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Cover Makaopuhi crater, Hawaii, from the west. See page 925. [R. T. Haugen, National Park Service]


Beckman

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Donna

Property damage in the continental United States: \$1 billion; lives lost: 17. Such is the estimate of the damage wrought by Donna, last month's major hurricane. What is most remarkable is that a storm so destructive of property claimed so few lives even though it hit heavily populated regions. Diane, in 1955, did half the damage and killed ten times as many people.

The difference is no chance variation. It is rather the pay-off on cooperative scientific and community efforts in the intervening years. Late in 1955 the National Hurricane Research Project was organized in the U.S. Weather Bureau. This project has had the close cooperation of all government agencies concerned and of several universities and other institutions working under contract with the bureau. In addition, the United States operates eight upper air stations cooperatively with other nations in the Caribbean Sea.

When Donna was first spotted on 2 September 1200 miles ESE of San Juan, Puerto Rico, an extensive network of weather stations, many equipped with special radars of 200-mile range, was ready to go into action. Navy, Air Force, and Weather Bureau planes were dispatched to fly into the hurricane. The data provided enabled forecasters both to make continuous predictions of Donna's course as she moved slowly westward across the Lesser Antilles and to correct these predictions as minor deviations occurred. The accurate prediction in Donna's course was a major factor in reducing the loss of life: precise warnings were given hours before she struck Miami on 10 September. But other factors played a part. The Weather Bureau, thanks to research about the way people react to emergencies by the Disaster Study Committee of the National Academy of Sciences –National Research Council, has developed more effective reports for the public. A person in the pathway is not so much interested in the exact position of the eye of the hurricane as in whether his house is likely to be wrecked, whether he is likely to be cut off or drowned by floods, and what steps he can take to protect himself. This kind of information was provided, but to do so it was necessary to predict which roads would be flooded by swollen streams or high tides. Studies of previous hurricanes in cooperation with the Coast and Geodetic Survey and the Army Corps of Engineers made it possible to predict high water with more precision than in the past.

So much for the scientific effort, which provided accurate information. Public cooperation also played an important role in saving lives. Broadcasts of information were effective, and the Red Cross and Civil Defense organizations as well as state and local governments worked together to evacuate people from hazardous places.

The whole episode is a gratifying example of cooperation—scientific, international, state and municipal, public and private. What of the future? Not much more can be expected from cooperation—it is hard to improve on near-perfection. The answer, if there is one, lies in further research. Why did a subsequent hurricane, Florence, which looked like Donna's twin sister at first, peter out? Will it be possible to predict the time and place of hurricane formation? Perhaps Donna, the most intensively studied hurricane in history, will suggest some answers as the vast mass of data gathered about her is analyzed during the coming months and years.—G.DuS.

7 October 1960, Volume 132, Number 3432 **SCIENCE**

CURRENT PROBLEMS IN RESEARCH

How Volcanoes Grow

Geology, geochemistry, and geophysics disclose the constitution and eruption mechanism of Hawaiian volcanoes.

J. P. Eaton and K. J. Murata

Summarizing the state of volcanological knowledge in 1952, Howel Williams (*1*) observed: "Much has been learned about the distribution, internal structure, and products of volcanoes, but pitifully little about the causes and mechanism of eruption." To remedy this deficiency he called for more intensive, continuous observations of well-chosen active volcanoes, with geophysics and geochemistry supplementing the traditional tools of geology. Current investigations of the U.S. Geological Survey's Hawaiian Volcano Observatory are much like those envisaged by Williams, and they are yielding an exciting new insight into the internal workings of volcanoes.

No volcano has influenced our conception of the vital processes of active volcanism more than Kilauea. Geologists drawn to Hawaii by travelers' accounts of fantastic activity at this volcano were so impressed by what they saw that they framed whole theories of volcanic action around it. Even though its prime attraction, the renowned lava lake that circulated almost continuously within its great summit caldera for at least a century, was destroyed in 1924, Kilauea and its giant neighbor, Mauna Loa, have remained very active, one or the other having erupted about once in two years since that date. The comparative simplicity, the large size, and the frequent, voluminous, nonviolent eruptions of Hawaiian volcanoes make them ideally suited to illustrate the fundamental processes of volcanism. Here these processes can be studied safely and conveniently, in isolation from the great complications of structure and contaminating rocks that render most volcanoes so baffling.

In 1823 William Ellis (*2*) found within Kilauea caldera "an immense gulf, in the form of a crescent, upwards of two miles in length, about a mile across, and apparently 800 feet deep. The bottom was filled with lava, and the southwest and northern parts of it were one vast flood of liquid fire in a state of terrific ebullition. . . ." Through the century that followed, visitors to Kilauea recorded successive infillings and collapses of Ellis' "gulf," as lava poured up through conduits beneath its floor and accumulated, crusted over, and partially congealed within it, later to be withdrawn into the depths or poured out through great fissures in the flank of the volcano.

Continuous observation of the lava lake began with the establishment of the Hawaiian Volcano Observatory on the rim of Kilauea caldera in 1912 (*3*). Detailed measurements of the height, size, and shape of the liquid surface of the lake (Fig. 1) as well as occasional measurements of its temperature and chemical analyses of the gases escaping from it were made from 1912 until the lake was destroyed by the eruption of 1924. The usefulness of seismograph and tiltmeter observations for deciphering unseen subterranean changes in the volcano was also demonstrated during these years when Jaggar (*4*) and his collaborators were collecting a wealth of data on Kilauea's baffling lava lake.

Setting and Geology

The geologic mapping of the Hawaiian Islands, carried out jointly by the U.S. Geological Survey and the Hawaii Division of Hydrography during the 1930's and 1940's, opened new dimensions in the study of Hawaiian volcanoes (*5*). A thorough investigation of volcanic processes necessarily awaited an adequate geological description of the volcanoes. By mapping structures visible at the surface, by examining the shallow interior of the volcanoes in the sections exposed by faulting and erosion, and by studying very carefully the nature, variation, and distribution of the lavas composing the great Hawaiian shields, geologists have sketched the framework of the volcanoes' structure and history.

Mauna Loa and Kilauea form the southern part of the island of Hawaii at the southeastern end of the Hawaiian Ridge, a great range of volcanic mountains rising from the floor of the Pacific Ocean and stretching 1600 miles northwestward from Hawaii to Kure Island (Fig. 2, inset). Volcanism appears to have progressed from the northwest toward the southeast along the ridge. Wave-wrecked volcanoes of the northwestern half of the ridge approach the surface as shoals or support low-lying coral atolls. Farther southeastward, remnants of volcanic rock rising in small islands still withstand the vanquishing sea. Only along the southeastern quarter of the ridge do the great volcanoes stand high above the sea, where they form the large inhabited islands of the Hawaiian group. Even here the evidence for migration of activity southeastward is strong, for volcanoes in the northwestern part of this group are deeply dis-

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Fig. 1. Lava lake in Halemaumau, 23 January 1918. Floating islands of congealed lava are surrounded by molten lava. In the foreground, an overflow from the lake has chilled to pahoehoe lava. In the background can be seen the wall of Kilauea caldera and the gentle slopes of the southwest rift zone of Mauna Loa.

sected, while Mauna Loa and Kilauea, still in vigorous activity at the southeastern end, are hardly marred by erosion.

From its great length and narrow width it is apparent that the Hawaiian Ridge marks the course of a major fracture in the earth's crust through which lava has poured at different centers and different times to build the volcanoes that form it. The ridge rises from the axis of a broad swell on the ocean floor and is flanked, near its southeastern end, by an ocean deep that runs down its northeast side and hooks around the south end of the island of Hawaii (*6*).

Volcanoes of the ridge are built upon the simplest known section of the earth's crust (the Pacific basin is floored only by approximately 5 kilometers of basalt, covered by about 1 kilometer of sediments and resting directly upon the earth's mantle), and they are separated from other tectonically active regions by at least 2000 miles of seismically quiet ocean floor. Thus, in magnificent isolation, volcanic processes originating in the mantle raise the giant Hawaiian mountains to heights approaching 6 miles (10 kilometers) above the ocean floor.

Hawaiian volcanoes bear little resemblance to steep-sided, central-type composite volcanoes like Fujiyama, in Japan. Rather, they are shaped like a warrior's shield, with a broad domical summit and gently sloping sides, and they attain enormous size. Mauna Loa rises more than 30,000 feet above its base on the ocean floor and has a volume of about 10,000 cubic miles. Even at sea level, about 16,000 feet above its base, it is more than 70 miles long. The volcanoes are built almost entirely of thin flows of fluid basaltic lava, poured out chiefly from long fissures concentrated in relatively narrow rift zones.

On surface evidence, rift zones appear to determine the location and shape of the volcanoes. Most commonly, each volcano has two principal rift zones meeting in the summit region at angles of 130° to 180°. The vertex of this angle usually points away from the unbuttressed flank of the Hawaiian ridge adjacent to the volcano. Rift zones are predominantly either almost parallel or more or less perpendicular to the axis of the ridge, but just how these zones are related to the fundamental fracture beneath the ridge is not clear.

The summits of several volcanoes are indented by calderas formed by collapse of the surface rocks when support was withdrawn from below. Kilauea caldera, subcircular in plan and eccentrically set in the summit of the volcano, is 2½ miles long and 2 miles wide. Its floor, a low dome of lava flows that slope outward from Halemaumau, site of the old lava lake and principal vent of Kilauea, is almost 500 feet below the caldera rim on the northwest but level with the rim on the south. The present floor is about 600 feet higher than that depicted in a sketch by Malden (*7*) in 1825.

Along some rift zones, especially near their upper ends, are found other prominent collapse craters. The variation in size as well as the nature of pit craters, as these features are called, is well demonstrated by the "Chain of Craters" along the upper section of Kilauea's east rift zone. Here, pit craters range from the "Devils Throat," formed by a single collapse that left a pit 50 feet across and 250 feet deep with an overhanging lip, to the giant Makaopuhi (Fig. 3), the result of at least two episodes of collapse and two of flooding by lava that formed a gulf almost a mile across and 900 feet deep.

Prominent lateral faults, some of them submarine, flank several of the volcanoes. Notable among these are the Honuapo-Kaoiki fault system, which separates Kilauea from Mauna Loa and extends from just north of Kilauea caldera southwestward to the sea near Honuapo, and the Hilina fault system (Fig. 4), which drops a 30-mile-long segment of Kilauea's south flank abruptly toward the sea. Although the absolute movement on these faults cannot be specified, it is distinctly possible that the wholesale uplift of the Hawaiian Ridge along such faults has been responsible for a significant fraction of its height.

Hawaiian lava flows, both the smooth, glassy-skinned pahoehoe and the indescribably rough, clinkery-surfaced aa, are intricately broken by the processes that form them. The volcanic edifices built of these shattered flows are mammoth piles of rubble, shored up beneath the rift zones by thousands of thin, nearly vertical dikes of strong, dense basalt. Their bulk density, estimated from measurements of gravity across the Hawaiian Ridge (*8*) and in deep wells on the island of Hawaii, is no greater than 2.3 grams per cubic centimeter, significantly less than the density, about 2.8 grams per cubic centimeter, of an unvesiculated column of basaltic magma at depth.

To judge from the historic and geologically recent behavior of Mauna Loa and Kilauea, Hawaiian volcanoes grow almost to their full size quite rapidly. Intervals between eruptions are only a

few years or decades, and the flanks of the volcanoes are blanketed by new flows so frequently that erosion makes little headway. The lavas forming these primitive shields belong to the "tholeiitic" basalt series and differ primarily only in their content of olivine crystals. Although surging fountains of gas-inflated lava are often propelled hundreds of feet into the air by gas released from the lava as it approaches the surface within the vent fissure, these eruptions show little real explosivity and build only small cinder cones, spatter cones, and spatter ramparts around their vents.

After the volcanoes reach maturity the interval between eruptions increases, perhaps to a century or more, erosion begins to predominate over growth, and subtle changes appear in the chemistry and mineralogy of the lavas, which pass over into the alkalic basalt series. Eruptions become more explosive, building larger cinder cones around the vents.

Even after Hawaiian volcanoes are overcome by old age and are transfigured by profound erosion, occasional renewals of volcanism pour out additional lavas of the alkalic basalt series or even more highly differentiated lavas such as the felspathoid-bearing flows of Oahu and Kauai.

The outstanding questions of the origin of magma, the mechanism of eruption, and the differentiation of magma are strongly interdependent, and any answer proposed for one must be compatible with data for the others. The mechanism of eruption plays a central role. It must account for how

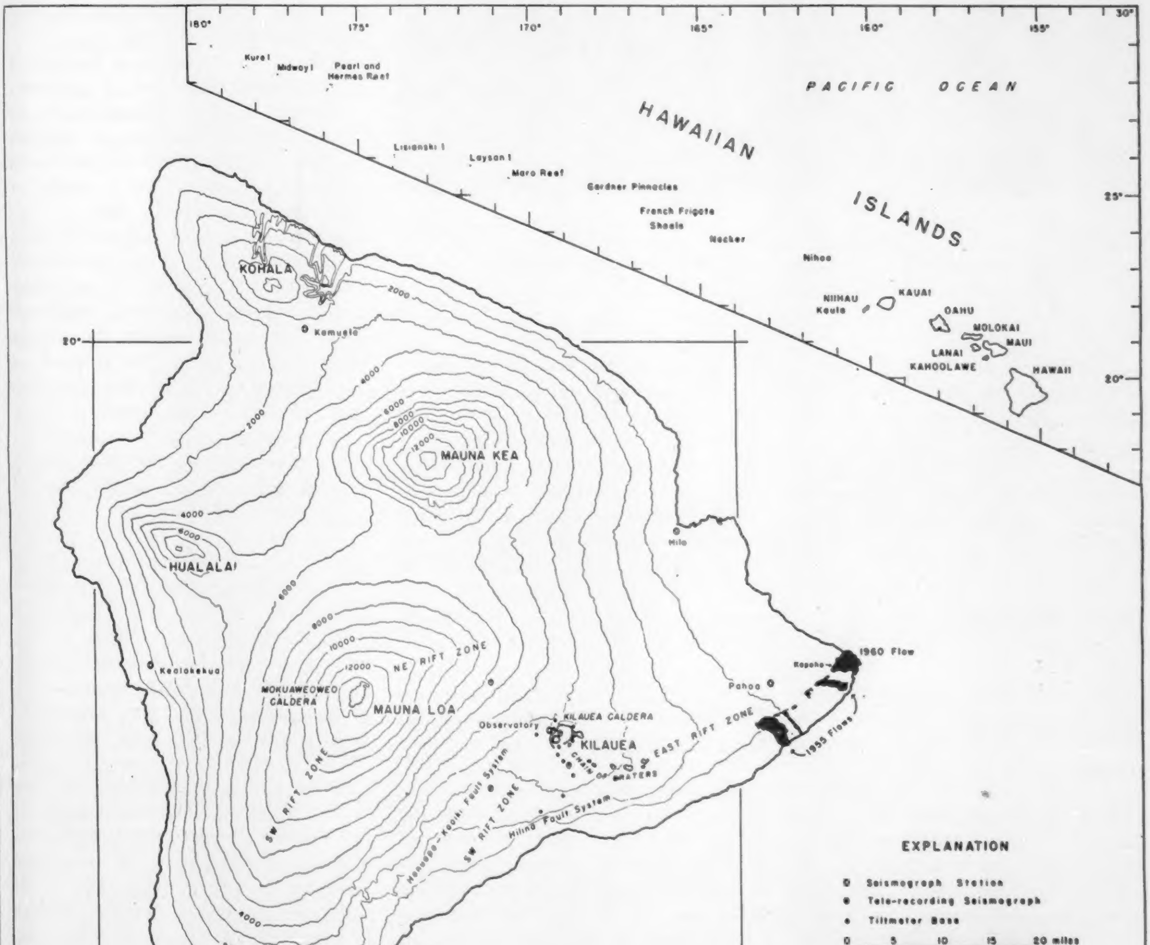

Fig. 2. Map of Hawaii showing seismograph stations, tiltmeter bases, and the Kilauea lava flows of 1955 and 1960. The inset shows the entire chain, stretching 1600 miles northwestward from Hawaii to Kure Island.

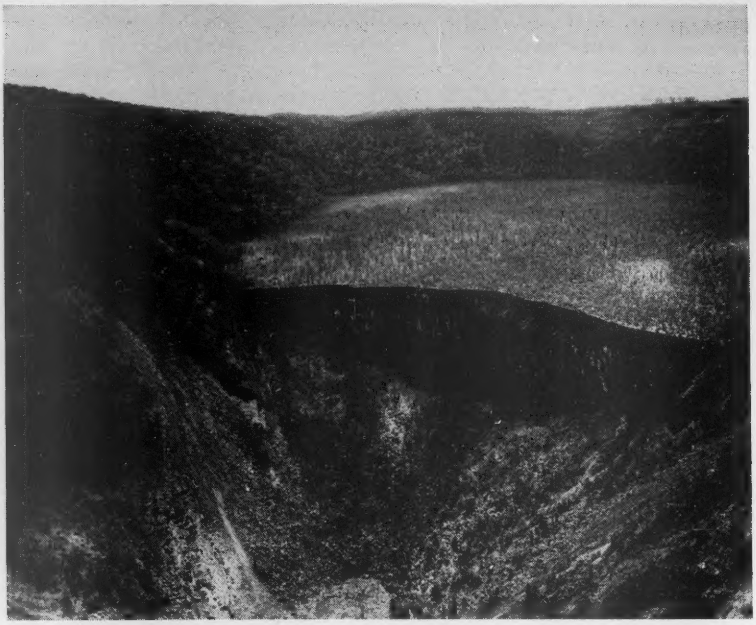

Fig. 3. Makaopuhi viewed from the west. A prehistoric lava pond, in the distance, was exposed by a later collapse in the foreground. The small pond of lava at the bottom of the deeper pit, 900 feet below the present rim, was poured into Makaopuhi in 1922. [R. T. Haugen, National Park Service]

and by what path magma is brought to the surface, why the volcanoes erupt intermittently, and how volcanic structures such as rift zones, pit craters, and calderas are produced, and it must provide the intratelluric environment necessary for the differentiation observed in the lavas.

Current Investigations

To extend the physical description of the volcanoes to depth and to obtain information on the active processes within them, the methods of geology must be supplemented by those of geophysics and geochemistry. During the last few years the staff of the U.S. Geological Survey Volcano Observatory in Hawaii has been augmented, and its facilities have been expanded and modernized to equip it for the necessary multidiscipline attack on the problems of Hawaiian volcanism.

A modernized seismograph network is giving us a better understanding of the internal structure of the volcanoes and is revealing some surprising evidence on processes within them. New instruments for measuring slight deformations of the earth's surface are providing information on the underground movement and accumulation of magma. Work at the Survey's recently constructed Geochemical Laboratory is helping to unravel the mysteries of origin, underground history, and petrographic variations of Hawaiian lavas through a systematic, detailed study of the chemistry and petrology of the lavas and of the chemistry of the gases given off by the volcanoes during and between eruptions.

Evidence from Geophysics

A variety of events within the volcanoes set up characteristic disturbances which are transmitted as elastic vibrations to the surface of the earth through the rocks composing the volcanoes and the crust and mantle of the earth beneath. These fleeting seismic pulsations carry vital information not only on the time, location, intensity, and nature of the events from which they spring, but also on the geologic structure and physical properties of the rocks through which they pass en route to the surface.

To capture these important data, a network of very sensitive seismographs is being developed in the Hawaiian Islands (Fig. 2). At the heart of the system four vertical-component seismometers, located in critical positions within a 15-kilometer radius of the observatory at the summit of Kilauea, transmit signals over telephone wires to the observatory, where four pens trace visible records of the motion of the ground at the seismometers. Seismographs in five other stations on the perimeter of the island of Hawaii provide critical additional data needed to locate earthquakes originating in and beneath the volcanoes, and seismographs in one station on Maui and one on Oahu extend the network to the distances required to permit the delineation of the structure of the crust under the Hawaiian Ridge.

Hawaii has earthquakes because it has volcanoes. In terms of numbers, practically all the earthquakes in the Hawaiian area occur in or beneath the active volcanoes and are intimately associated with eruptions. A significant few, however, including most of Hawaii's largest, originate on lateral faults at some distance from the calderas and rift zones that give rise to so many quakes during eruptions. Although some earthquakes along the lateral faults originate at depths as great as 30 kilometers, most of them are relatively shallow. They appear to mark gross readjustments in the rocky basement in response to the slow growth of the volcanoes and to the internal forces that build them.

Findings on the relation between travel time and distance for the strong seismic waves generated by large earthquakes on Hawaii and transmitted through the Hawaiian Ridge or refracted through the crust and mantle below to the most distant seismographs of the network are the data from which we can compute the "structure" of the earth beneath the volcanoes. Conventional interpretation of the travel-time curves indicates that there is a layered structure which represents a broad approximation of conditions along the Hawaiian Ridge. The implication of flat-lying, smooth contacts between discrete rock units should not be taken literally, especially for the portion of the structure lying above the level of the ocean floor surrounding the islands.

The near-surface speed of the longitudinal wave, *P*, is surprisingly low, only about 3 km/sec, and testifies to the loose, rubbly nature of the flows composing the shields. From a mod-

erate depth below the surface (here taken as about sea level) to a depth of several kilometers below sea level, the speed of P is about 4 km/sec. Below a depth of 3 kilometers the speed of P jumps abruptly to about 5.25 km/sec. The travel-time curves suggest that the speed of P increases still more, perhaps by a slow transition rather than an abrupt increase, to about 6.8 km/sec in the crust above the mantle. At a depth of about 14 kilometers the speed of P jumps to 8.25 km/sec, marking the top of the earth's mantle at the Mohorovičić discontinuity. These data are plotted in Fig. 5 with those obtained by Raitt (*9*) from a seaborne seismic profile off the coast of Hawaii. Of special interest is the close correspondence in the depth to the Mohorovičić discontinuity beneath the ocean and beneath the Hawaiian Ridge. It appears that the crust under Hawaii has been only slightly depressed by the enormous volcanoes built upon it.

An accurate knowledge of just where earthquakes originate within the volcanoes is very important to our understanding of internal structure. Earthquakes do not occur at random but are concentrated in zones or along structures undergoing strain. Thus, from the earthquakes that occur beneath the Honuapo-Kaoiki fault system, which separates the southwest flank of Kilauea from Mauna Loa, we know that the system extends to a depth of at least 15 kilometers and that it is still very active. Likewise, earthquakes originate from near the surface to depths as great as 30 kilometers along the Hilina fault system just south of Kilauea caldera, but farther east along this fault system earthquakes originating from depths greater than 10 kilometers are rare. Since about 1955, when a seismograph network capable of making reasonably accurate focal-point determinations was developed, the deepest earthquakes in the Hawaiian area have been recorded from a zone approaching a depth of 60 kilometers beneath the summit of Kilauea. In addition, thousands of quakes originate at shallow depths in the vicinity of Kilauea caldera when the volcano is swelling or shrinking in response to the movement of magma below. During the last two major eruptive cycles the east rift zone of Kilauea has produced only very shallow earthquakes, except very close to the caldera, and probably does not extend to a depth lower than the ocean floor.

Insight into processes at work in the volcanoes can also be gained from the nature, sequence, or association of disturbances recorded on the seismo-

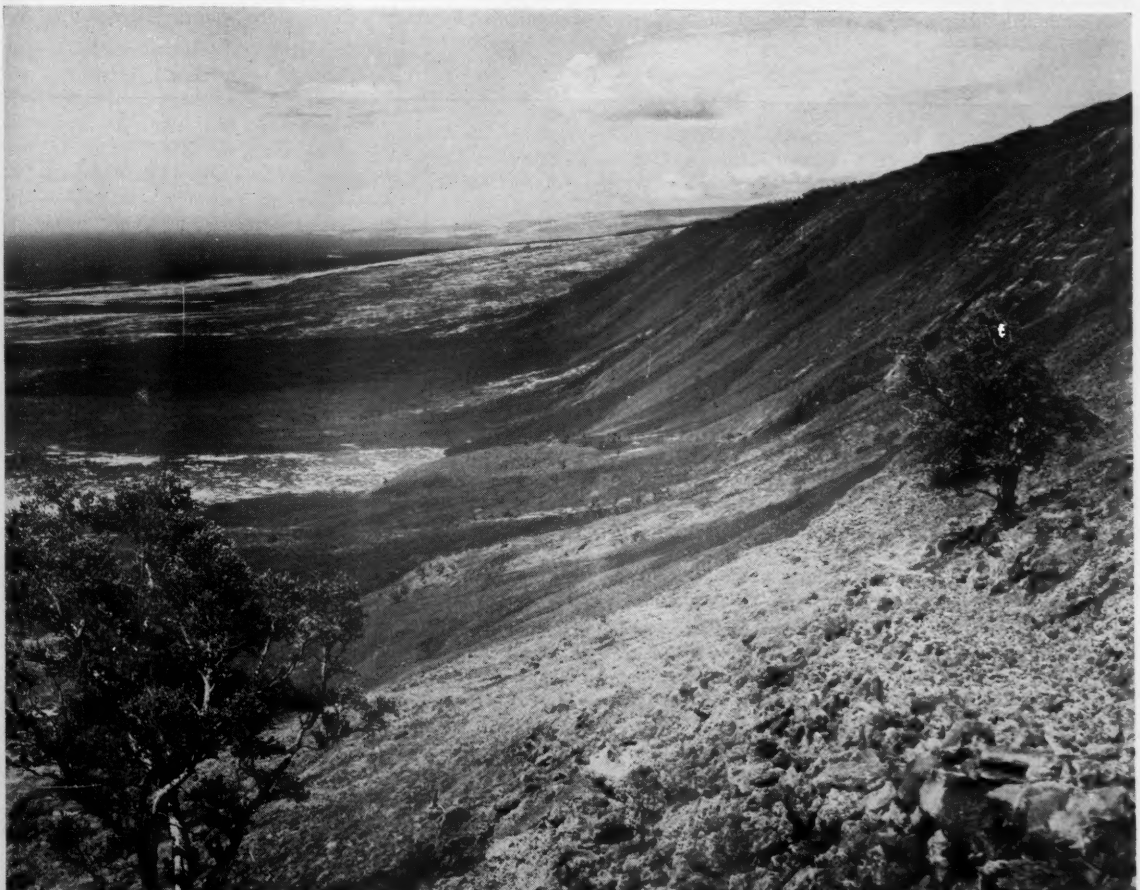

Fig. 4. Hilina Pali fault scarp. This scarp, 1500 feet high, has been almost completely mantled by recent prehistoric lava flows. View is toward the southwest.

graphs. Some of these disturbances are quite unearthquake-like and are apparently generated only by active volcanoes. When lava is pouring out at the surface during an eruption the entire region around the vent rocks gently to and fro as long as the vent is active. From seismographic evidence we know that this disturbance, called harmonic tremor from the sinusoidal nature of its seismic record, is generated near the earth's surface, probably by the rapid flow of magma through the feeding conduits. Because harmonic tremor rarely occurs when no eruption is in progress, its occurrence is excellent evidence that lava is streaming through conduits underground.

Great swarms of small earthquakes accompany several different processes in the volcano. Unlike a large tectonic earthquake and its aftershocks, where one large quake is followed by many smaller ones, the earthquakes in these swarms are uniformly small. The swarm usually begins slowly, rises to a maximum (in both average size and frequency of earthquakes), and then dies off slowly or abruptly, according to the nature of the process generating the earthquakes. Moderate swarms of tiny, sharp, highly localized earthquakes accompany the extension of dikes toward the surface before eruptions. Such swarms cease abruptly when lava pours out at the surface. More impressive swarms of larger, shallow quakes scattered through the summit of Kilauea attend the rapid subsidence of the caldera and its environs when lava drains out through the rift zone of the volcano during flank eruptions. These swarms begin and end gradually.

Occasionally great swarms of tiny-to-moderate, sharp earthquakes, totaling several thousand during the few days they last, emanate from depths between 45 and 60 kilometers beneath the summit of Kilauea. These are the deepest quakes that occur in Hawaii, and they bear no immediate, obvious relation to events closer to the surface. Usually they are accompanied by many hours of continuous, somewhat irregular tremor (spasmodic tremor) of weak-to-moderate intensity. The zone from which these disturbances stem is deep within the earth's mantle, three to four times deeper than the Mohorovičić discontinuity under Kilauea. Such activity appears to mark the zone from which magma is collected and fed into the system of conduits leading to the heart of Kilauea. If the magma rises from greater depths, this is at least the deepest zone in which its upward migration is marked by detectable seismic disturbances.

Whether Mauna Loa has a separate source of such activity beneath its summit we cannot yet say. No such source has been detected in the last five years, since sensitive seismographs have been in operation on Hawaii, but neither has Mauna Loa shown any sign of unrest during this interval.

Although seismic disturbances disclose what is happening within the volcano and when and where these changes are occurring, they tell us very

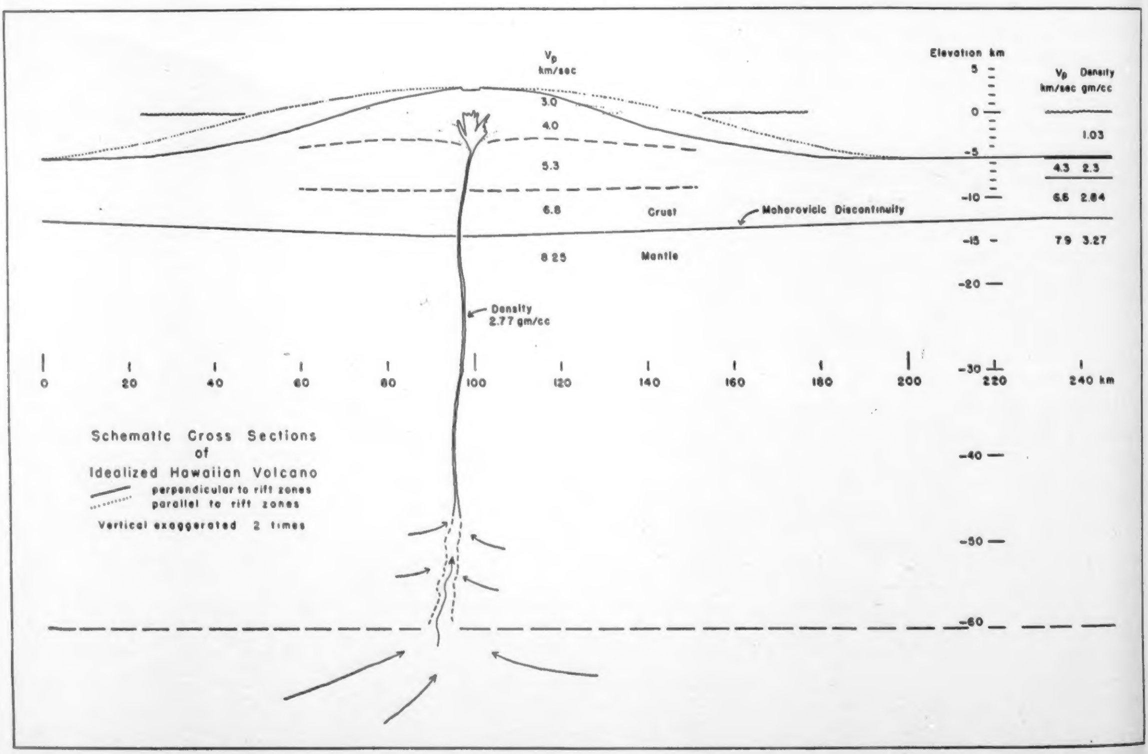

Fig. 5. Schematic cross sections of an idealized Hawaiian volcano. Magma from a source about 60 kilometers deep streams up through permanently open conduits and collects in a shallow reservoir beneath the caldera. Occasional discharge of lava from the shallow reservoir through dikes that split to the surface constitute eruptions. Note the elongation of the volcano along the rift zones and the relatively slight depression of the Mohorovičić discontinuity beneath the volcano. Data for the oceanic cross section on the right are from Raitt (*9*) and Worzel and Shurbet (*13*).

little about the likelihood that a particular disturbance will culminate in an eruption. Geophysical measurements of another sort, the measurement of tilting of the ground surface around the summit of the volcano, provide more direct evidence on the readiness of the volcano to erupt. As lava wells up within the volcano the surface of the ground above bulges upward and the flanks of the bulge tilt outward, and when an eruption pours the lava out at the summit or on the flank of the volcano, the ground above the emptying reservoir subsides.

Before an eruption these changes are subtle and slow, and extreme care is required to detect them. Conventional tiltmeters are sufficiently sensitive, but they are so strongly influenced by accidental local vagaries of earth structure and weather that their records are unreliable. To provide high reliability as well as high sensitivity and to make it possible to set up many low-cost tilt-measuring stations, an unconventional tiltmeter employing permanent tilt bases and an ultrasensitive, portable, water-tube leveling system has been developed. Successive relevelings at a tilt base, which consists of three permanent piers set in the ground at the vertices of an equilateral triangle 50 meters on a side, can detect tilting of the earth's surface as slight as 1 millimeter in 5 kilometers (*10*).

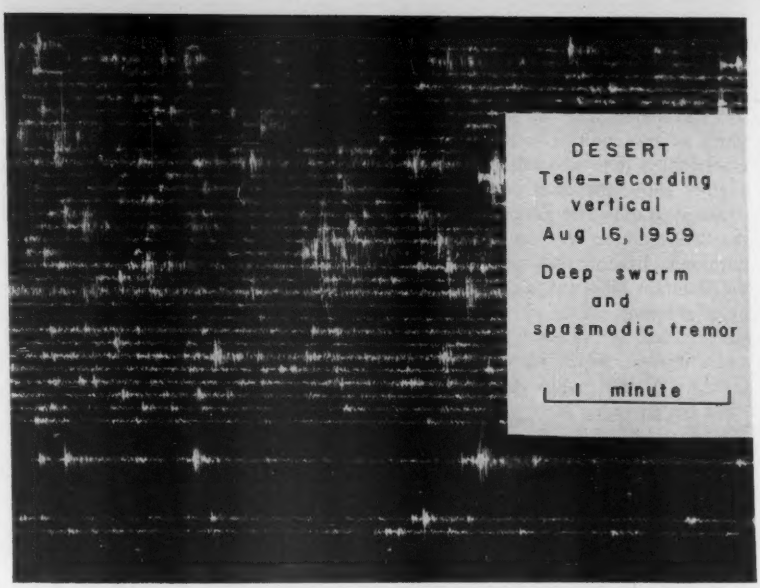

Fig. 6. A swarm of deep earthquakes and spasmodic tremor that originated about 55 kilometers beneath Kilauea caldera on 16 August 1959. Such activity appears to mark the movement of lava into the conduits beneath Kilauea. This seismogram was recorded on smoked paper at the observatory, 14 kilometers from the desert seismometer that detected these disturbances.

Case History: Kilauea Eruption, 1959–60

Even while the water-tube leveling system was being refined and tested between November 1957 and August 1958, preliminary readings on an experimental tilt base at Uwekahuna showed that the ground surface was tilting steadily outward from the caldera. By October 1958, measurements at additional tilt bases newly installed in a ring around the caldera revealed that the entire caldera rim was tilting outward. Analysis of tilting around the summit of Kilauea detected by the expanding network of tilt bases between October 1958 and February 1959 indicated that the entire summit region was swelling as magma slowly welled up from the depths and accumulated a few kilometers beneath the south rim of the caldera.

After the occurrence of several moderate earthquakes just southeast of the caldera on 19 February, the swelling stopped, and from May until August the summit of the volcano subsided slowly. Then a great swarm of deep earthquakes and associated tremor from a source about 55 kilometers deep and a few kilometers northeast of the Kilauea caldera kept Hawaiian seismographs in almost constant agitation between the 14th and 19th of August (Fig. 6). Magma moving into conduits beneath Kilauea during this episode made itself felt at the surface shortly, for rapid swelling of the volcano resumed between August and October (Fig. 7, inset *A*).

In its early stages, swelling of Kilauea took place with little or no seismic accompaniment. Lava rose from the depths and streamed slowly toward the shallow reservoir. At most, occasional intervals of weak harmonic tremor, originating perhaps 5 to 15 kilometers beneath the surface and lasting about half an hour, marked the lava's upward migration.

In the months preceding the 1959 outbreak of Kilauea there was no general increase in seismic activity, as there had been before the 1954 eruption. The first suspicious sign appeared during September 1959, when a series of very shallow, tiny earthquakes began recording on the North Pit seismograph on the northeast rim of Halemaumau. By the first of November, quakes of this swarm exceeded 1000 per day, but they were so small they barely were recorded on other seismographs only one mile away. A hurried remeasurement of tilting at bases around the caldera during the second week of November revealed that dramatic changes were in progress: the summit of Kilauea was swelling at least three times faster than during previous months (Fig. 7, inset *A*). In mid-afternoon on 14 November earthquakes emanating from the caldera suddenly increased about tenfold in number and intensity. At frequent intervals during the next 5 hours the entire summit region shuddered as earthquakes marked the rending of the crust by the eruptive fissure splitting toward the surface. Then, at 8:08 P.M., the lava broke through in a half-mile-long fissure about half-way up the south wall of Kilauea Iki crater, just east of Kilauea caldera. Abruptly the swarm of earthquakes stopped, and seismographs around the caldera began to record the strong harmonic tremor characteristic of lava outpouring from Hawaiian volcanoes (Fig. 8).

During the next 24 hours the erupting fissure gradually shortened until only one fountain remained active. But

then the rate of lava outpouring, which had decreased as the erupting fissure shortened, began to increase again, and it continued to increase steadily until the fountain died out suddenly on 21 November. The 40 million cubic yards of lava poured into Kilauea Iki crater filled it to a depth of 335 feet, slightly above the level of the vent.

Seismographs and tiltmeters warned that the eruption was not over. Feeble harmonic tremor that persisted after the fountain died was soon augmented by a growing swarm of tiny, shallow quakes such as preceded the eruption; and tiltmeters, which recorded a rapid deflation of the shallow lava reservoir while the fountain poured out its lava, revealed that the volcano was being inflated rapidly once more (Fig. 7). At 1:00 A.M. on 26 November the main vent of the first phase of the eruption revived. By 4:35 P.M. an additional 4.7 million cubic yards of lava had poured into the pond, increasing its depth to 350 feet and raising its surface high above the level of the original vent. Again the fountain died abruptly, and this time lava began to pour back down the vent. By 12:30 P.M. the next day 6 million cubic yards of lava had disappeared from the lake, leaving a black ring of frozen lava 30 feet above its receding surface.

During the following three weeks 14 more eruptive phases of shorter and shorter duration but with increasingly vigorous fountaining took place at the Kilauea Iki vent (Fig. 9). The highest fountain was measured during the 15th phase, on 19 December, when a column of incandescent, gas-inflated lava jetted to 1900 feet, by far the greatest fountain height yet measured in Hawaii. At its highest stand, at the end of the eighth phase, the lava pond was 414 feet deep and contained 58 million cubic yards of lava. At the end of each phase the fountain died abruptly, and from the 2nd to the 16th phase, a mighty river of lava surged back down the vent as soon as the fountaining stopped (Fig. 10). Of the 133 million cubic yards of lava spewed out into

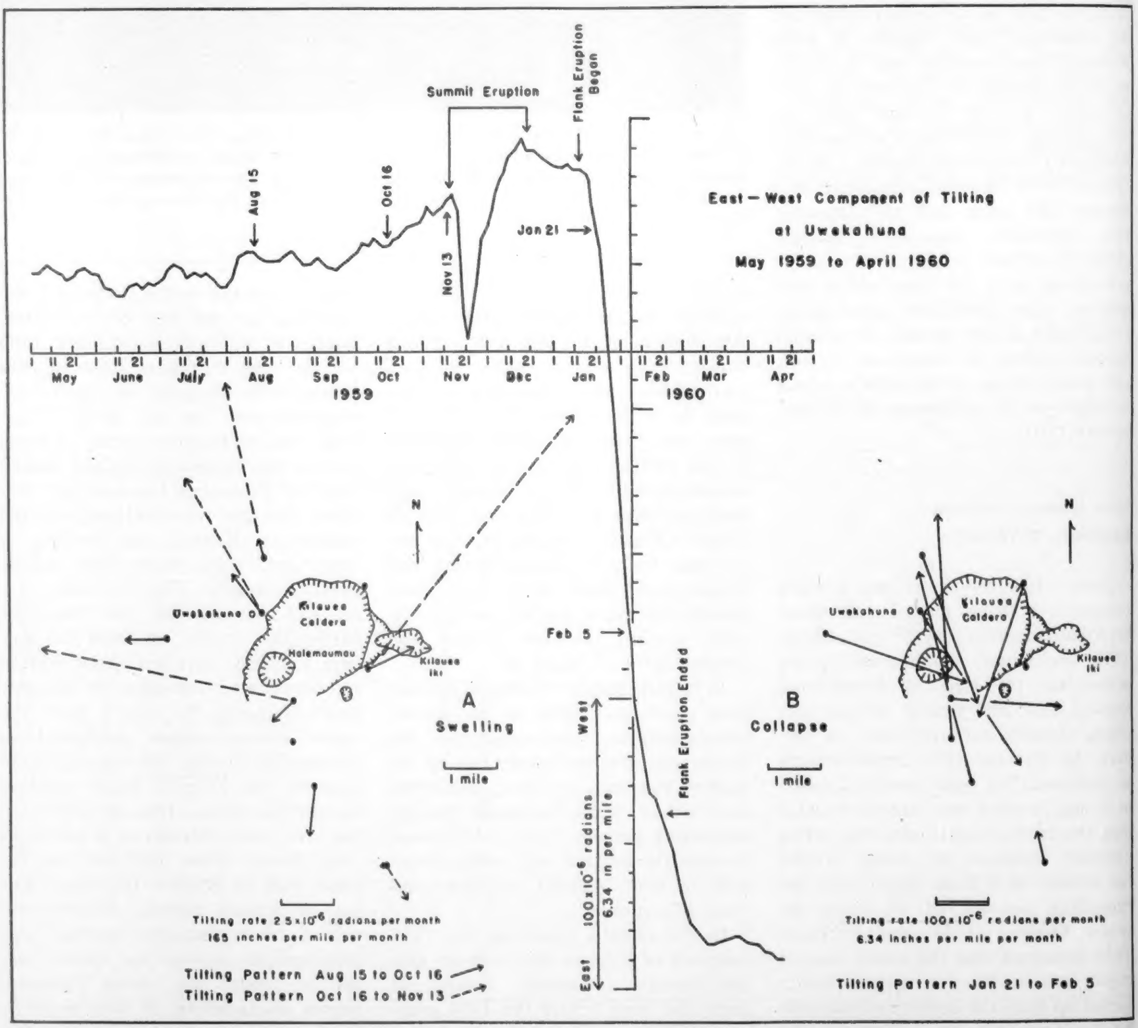

Fig. 7. Ground tilting at stations around Kilauea caldera associated with the 1959–1960 eruption. The east-west component of tilting at Uwekahuna shows the swelling and collapse of the summit of Kilauea as a function of time. Westward tilting (up) corresponds to swelling, and eastward tilting (down), to collapse. Inset *A* illustrates the pattern of tilting around the caldera during two periods of swelling. Inset *B* illustrates the pattern during collapse. Note the 40-fold difference in scale between *A* and *B*.

Kilauea Iki crater during the eruption, only 48 million cubic yards remains in the 367-foot-deep pond. The other 85 million cubic yards poured back underground almost as soon as it collected in the Kilauea Iki lava pond, where its volume could be so conveniently measured.

Tiltmeters around Kilauea caldera showed that the volcano was swelling rapidly as phase after phase of the eruption delivered its lava to the surface and then swallowed it up again. When surface activity ceased at Kilauea Iki on 21 December, far more lava was stored in the shallow reservoir beneath the caldera than when the eruption began (Fig. 7). It appeared that Kilauea was in an unstable state and that further activity was very likely.

During the last week of December a swarm of small earthquakes began to record on the seismograph at Pahoa. By means of a sensitive portable seismograph the source of these earthquakes was soon traced to the east rift zone of Kilauea, about 25 miles east of the caldera, near the site of the first outbreak of the 1955 eruption (Fig. 2). The magma that inflated the summit region most probably exerted pressure on the plastic core of the rift zone, and earthquakes revealed where the rift zone yielded and where dikes began to extend toward the surface.

Early in January the frequency and size of earthquakes from the east rift zone increased, and the region from which they emanated moved on toward the sea. On 13 January the village of Kapoho was rocked by frequent, very shallow earthquakes, and by nightfall a graben 0.5 mile wide and 2 miles long that contained about half of the town had subsided several feet. At 7:30 P.M. the earthquake swarm gave way to harmonic tremor, and the flank eruption broke out along a fissure 0.75 mile long near the center of the subsiding graben, a few hundred yards north of Kapoho and nearly 30 miles east of the summit of Kilauea.

During the next five weeks nearly 160 million cubic yards of lava poured out of the vent north of Kapoho and reshaped the topography of the eastern tip of Hawaii (Fig. 2). As the flow from the vent to the sea 2 miles away gradually built higher and higher, lava crowded out of the natural channel that initially confined it. Sluggish flows spread laterally from the main channel, destroying almost all of Kapoho, south of the vent, and most of the village of Koae, north of the vent. Dikes 15 to 20 feet high, built in a futile attempt to confine or divert flows that threatened a residential community along the seashore 2 miles southeast of Kapoho, were completely overwhelmed, and the lava moved on to destroy a portion of that community.

On 17 January, only four days after the flank eruption began, the summit of Kilauea began to subside precipitously as lava began to drain from beneath

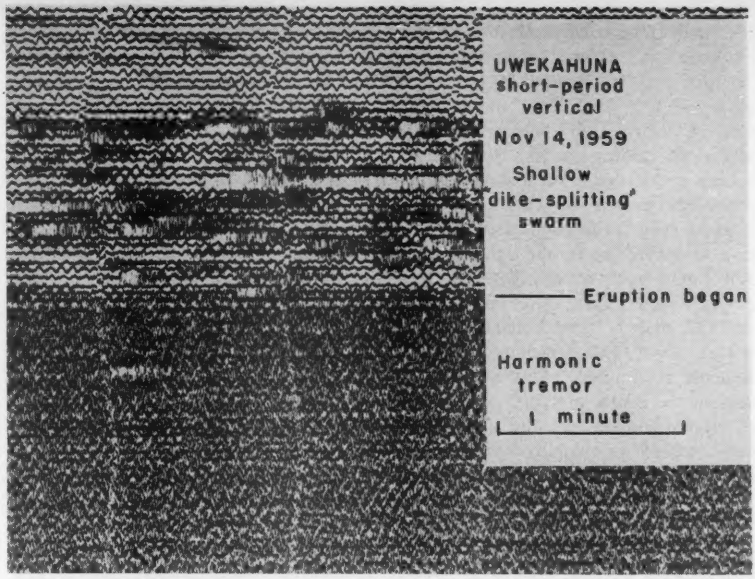

Fig. 8. Seismogram showing a swarm of shallow earthquakes immediately preceding the eruption in Kilauea Iki, followed by harmonic tremor caused by lava streaming through the erupting fissure near the surface. This seismogram is from a short-period vertical seismograph at Uwekahuna.

Fig. 9. Five-hundred-foot lava fountain in Kilauea Iki crater at 7:00 A.M. on 5 December, 1959. Note the new cinder cone at left of the fountain and the lake of fresh lava 400 feet deep in the foreground. The west wall of Kilauea caldera and the southeast flank of Mauna Loa are in the background of the picture, which was taken with the camera facing west.

the caldera and to move through the rift zone toward the Kapoho vent (Fig. 7, inset *B*). By the end of January a strong swarm of shallow earthquakes was in progress at Kilauea caldera, where the brittle surface rocks were failing under the rapid and severe deformation caused by continuing subsidence (Fig. 11). On 7 February an unseen fissure broke through into the still liquid core of the 300-foot-deep pond of lava erupted into Halemaumau in 1952, and the floor of Halemaumau settled about 150 feet as the liquid beneath it drained away. A smaller area in the center of the floor dropped an additional 200 feet, but it was partially refilled by sluggish flows of viscous lava draining from under the subsiding crust of the pond around it.

By the first of April, when rapid subsidence and the swarm of earthquakes it caused had ceased, tiltmeters around the summit indicated that the ground surface above the shallow reservoir that was deflated during the flank eruption had sunk about 5 feet. The total volume of collapse at the summit (the volume swept out by the surface of the volcano as its summit subsided), estimated from tiltmeter data, is close to the total volume of lava erupted at the surface.

Comparisons of temperatures and silica content of the lava erupted at Kilauea Iki and at Kapoho provide additional data on the underground history of Hawaiian lava. Temperatures measured in the core of the fountain at Kilauea Iki were consistently above 1120°C (measured with a hot-wire optical pyrometer and uncorrected for departure from black-body radiation). During a single phase of the eruption the temperature of the lava usually increased from about 1120°C near the beginning of the phase to about 1150°C near the end. The maximum temperature was measured during the fourth phase, when 1190°C was recorded. During early phases the silica content of the lava varied between 46.3 and 49.5 percent, but after the fourth phase it stabilized at about 46.8 percent. Petrographically the lava is a tholeiitic picrite basalt, consisting of olivine phenocrysts set in a fine-grained groundmass of plagioclase feldspar, pyroxene, and glass.

The lava erupted during the first two weeks of the flank eruption closely resembled the lava erupted in the same region in 1955. These lavas are tholeiitic basalts, poor in olivine but containing abundant phenocrysts of plagioclase feldspar and pyroxene. The silica content was about 50 percent, and the temperature was only 1050° to 1060°C, fully 100°C cooler than the lava at Kilauea Iki. After the second week the lava emerging from the Kapoho vent began to change; the silica content dropped, and the temperature increased. During the last week of voluminous lava eruption in February the temperature reached a maximum of 1130°C and the composition approached that of the lava erupted at Kilauea Iki.

It seems quite probable that the lava poured out during the first two weeks of the flank eruption had remained stored in the rift zone since at least 1955, if not since 1924, when lava drained from the summit into the east rift zone but failed to reach the surface. The chemical composition and mineralogy of this lava reveal a degree of differentiation that is unusual for Kilauea. The last lava erupted at Kapoho petrographically resembles Kilauea Iki lava, and it is entirely possible that magma moved from the summit reservoir, down through the rift zone, to the Kapoho vent during the course of the flank eruption.

Origin of the Magma

Although the geophysical evidence presented above permits us to trace the movement of magma through the volcano, it does not suggest why nor how magma enters the volcano at depth and rises through it to heights approaching 10 kilometers above the ocean floor to pour out at the surface. The "ascensive force of the lava," as it was called by Dana (*11*), was attributed by Daly (*12*) to the lower average density of the column of lava

Fig. 10. A river of lava pouring back into the Kilauea Iki vent at 7:30 A.M. on 19 December 1959. The top of the cone is 400 feet higher than the vent. The picture was taken with the camera facing south.

as compared to that of the crust of the earth above the zone in which the lava begins its journey to the surface. New information on the structure of the earth's crust beneath the Pacific basin requires that we revise the details of the model presented by Daly. We suggest that the crust here is much thinner than he believed it to be, and few geologists would now subscribe to the view that there is an eruptible basaltic glassy substratum underlying a crystalline crust. In principle, however, no better explanation of the ascensive force has been offered than that proposed by Daly.

If we assign densities to the molten lava column and to the various earth layers reported by Raitt for the Pacific basin in the Hawaiian region, we can compute the minimum depth at which lava can enter the volcanic system and be forced to the summits of the volcanoes. The densities given in Fig. 5 for the layers in Raitt's oceanic crust are those of the standard oceanic crustal gravity section adopted by Worzel and Shurbet (*13*). For the average density of the basaltic lava column we shall adopt Daly's estimate of 2.77 grams per cubic centimeter. Balancing the densities of the lava column and the crust, we find that to raise the lava z kilometers above sea level the lava column must extend at least to a depth x below sea level, where $x = 32.34 + 5.54\ z$ kilometers. Thus, to raise lava to the summit of Kilauea (1.2 kilometers), the lava column must extend to a depth of at least 39 kilometers below sea level; and to raise lava to the summit of Mauna Loa (4.2 kilometers), it must extend to a depth of at least 57 kilometers. These figures are in good agreement with the depth at which, according to the evidence of swarms of deep earthquakes and tremor, lava is fed into the Kilauea system.

Data from still another quarter, the study of surface waves of large earthquakes, throw additional light on the origin of Hawaiian lavas. Recent analyses of the dispersion of Rayleigh waves crossing the Pacific basin reveal that the rigidity of the mantle decreases somewhat at a depth of 60 kilometers (*14*). In view of the two other lines of evidence suggesting that Hawaiian magma originates at about this depth, it seems reasonable to conclude that the softening of the mantle at 60 kilometers is caused by partial melting of a peridotite mantle to yield an eruptible basaltic fraction. Perhaps, to go back to glassy substratum like that postulated by Daly but of higher density, the cooling and the consequent partial crystallization of a noneruptible, dense, glassy mantle drives off a lighter basaltic fraction that can be erupted to the surface.

Fig. 11. Seismogram showing a swarm of shallow earthquakes caused by rapid subsidence and deformation of the summit of Kilauea. This swarm lasted for several weeks. The seismogram was recorded on a short-period vertical seismograph at Uwekahuna.

Mechanism, Composition, and Kinetics of Eruption of the Lavas

Let us recapitulate the evidence on the mechanism of eruption presented above and examine, by following the magma on its course through the volcano, how that mechanism explains surface geologic features. When magma enters the deep conduit beneath Kilauea (a portion of the fundamental fracture beneath the Hawaiian Ridge that is currently active) it begins a slow ascent through the heated depths toward the cooler crust and volcanic pile above. The movement of magma into the conduit at depth is relatively slow and steady, being governed, perhaps, by the rate at which the magma can be separated from the mantle and funneled into the open conduit. After leaving the upper portion of the mantle and traversing the basaltic layer that floored the ancient ocean, the magma emerges into the lighter, weaker rocks composing the volcanic pile and collects in a reservoir only a few kilometers beneath the surface. Upwelling of lava and consequent inflation of the high-level reservoir are slow processes that continue for months or even years prior to an eruption. Mounting pressure within the expanding reservoir finally drives the magma into dikes that split the frozen crust above the reservoir. When one of these dikes breaks through to the surface, an eruption ensues; the reservoir shrinks, and the pressure within it decreases as lava is discharged.

Basalt occupies a key position in modern theories of petrogenesis, and most, if not all, other kinds of igneous rocks are considered to have their ultimate origins in basaltic magmas. Thus, the chemical differentiation of basaltic magmas is a fundamental geochemical problem that has occupied the attention of many investigators throughout the world. Study of this differentiation in basaltic areas on the continents is complicated by the ever-present possibility that basaltic magmas may become contaminated by the diverse rocks that make up the crust of the continents. In the Hawaiian province, with its simple basaltic substratum, the possibility of such contamination is minimal, so magmatic differentiation may be investigated here with confidence.

Occasionally magma from the main reservoir is driven laterally into the mobile core of a rift zone, and failure of the confining rocks at some point along the rift results in a flank eruption,

Table 1. Chemical composition of typical Hawaiian rocks (these compositions are plotted on Fig. 12).

Compound	Tholeiitic basalt series*				Alkalic basalt series†		
	A	*B*	*C*	*D*	*E*	*F*	*G*
SiO_2	50.94	50.08	46.59	62.23	50.09	62.19	43.28
Al_2O_3	12.97	13.73	6.69	12.03	19.49	17.43	14.43
Fe_2O_3	1.95	1.32	2.20	5.55	0.73	1.65	0.70
FeO	8.96	9.79	10.46	4.76	8.47	2.64	10.92
MgO	10.68	7.89	21.79	2.05	4.33	0.40	11.68
CaO	9.88	11.50	7.41	4.25	6.92	0.86	11.22
Na_2O	1.99	2.18	1.33	3.20	4.82	8.28	2.49
K_2O	0.37	0.56	0.28	1.36	1.93	5.03	0.83
H_2O^+	0.12	0.02	0.37	0.33	.32	0.39	0.05
H_2O^-	0.04	0.00	0.04	0.52	.08	0.14	0.03
TiO_2	1.78	2.60	1.83	2.18	2.47	0.37	4.12
P_2O_5	0.21	0.26	0.11	0.01	0.78	0.14	0.31
MnO	0.17	0.17	0.18	0.43	0.15	0.32	0.13
CO_2	0.04	0.01				0.02	
Cr_2O_3			0.13			tr.	0.10
NiO			0.12				
SO_3			0.00			0.00	0.20
Total	100.10	100.11	100.53	99.21‡	100.58	99.93§	100.54‖

*(*A*) Tholeiitic olivine basalt, Mauna Loa, at highway at south boundary of Waiakea Forest Reserve, 2.65 km northwest of the Olaa sugar mill, island of Hawaii. Analyst, L. N. Tarrant (*31*). (*B*) Tholeiitic basalt, Kilauea, splash from lava lake, 1917, island of Hawaii. Analyst, L. N. Tarrant. Reanalysis of a previously described sample. New analyses published with permission of H. A. Powers (*19*). (*C*) Mafitic gabbro porphyry, Kilauea, Uwekahuna laccolith in the wall of the caldera, island of Hawaii. Analyst, G. Steiger (*32*). (*D*) Granophyre, Koolau Volcano, quartz dolerite dike at Palolo quarry in the southeastern part of Honolulu, island of Oahu. Analyst, K. Nagashima (*33*). †(*E*) Hawaiite (andesine andesite), Mauna Kea, elevation 2700 feet, on northwest flank near Nohonaohae, island of Hawaii. Analyst, H. S. Washington (*16*). (*F*) Trachyte obsidian, Hualalai, Puu Waawaa, island of Hawaii. Analyst, W. F. Hillebrand (*15*). (*G*) Picritic alkalic basalt, Haleakala Volcano, lava flow of 1750(?) on the southwest slope near Makena, island of Maui. Analyst, M. G. Keyes (*34*). ‡Includes 0.31 SrO. §Includes 0.03 BaO and 0.04 ZrO_2. ‖Includes 0.05 BaO.

sometimes miles from the summit of the volcano. Discharge of lava at a low elevation along a rift zone can cause a much greater drop in reservoir pressure than can result from a summit eruption. The volume of flank eruptions and the consequent reservoir deflation and ground-surface subsidence are much larger than for summit eruptions.

Rift zones, like the central reservoir, appear to be relatively shallow structures. They are zones split by countless dikes seeking to discharge lava at a low elevation through a long channel that cuts the cold crust in competition with other dikes that provide shorter channels through the cold crust to higher elevations near the summit. Concentration of these dikes in a zone and the ultimate generation of a molten rift-zone core result from the tendency for each dike to heat the rocks around it and lessen the freezing effect of the cold crust on later dikes that follow nearby paths.

Rapid, severe deflation of the central reservoir or of its lateral protrusions into the rift-zone cores can lead to the collapse of the ground surface by withdrawal of support from below. This process, which is especially severe for flank eruptions far down the slopes of the volcano, seems to be responsible for the formation of pit craters and calderas.

The work of Cross (*15*), Washington (*16*), Macdonald (*17*), Wentworth and Winchell (*18*), and Powers (*19*), among others, has disclosed a wide range in chemical composition among Hawaiian basaltic lavas and has established the broad outline of genetic relationships among rocks of different composition. Analyses of typical examples of the different types of Hawaiian rocks are given in Table 1.

The division of basaltic rocks into a tholeiitic series and an alkalic series, first made for the basaltic rocks of Scotland by Bailey and others (*20*), is also useful in the study of the Hawaiian rocks, as was recently shown by Tilley (*21*). As emphasized by Macdonald (*17*), the fundamental primitive magma of Hawaii is tholeiitic olivine basalt (Table 1, sample *A*). Sample *A* closely approximates the average composition of tholeiitic lavas from the currently active mature volcanoes Kilauea and Mauna Loa, and this general type of lava makes up the great bulk of each of the Hawaiian Islands. Rocks of the alkalic basalt series are produced in lesser quantities in the declining stages of volcanic activity and, on the island of Hawaii, characteristically occur as mantles over the tholeiitic shields of the extinct or late-stage volcanoes Mauna Kea, Kohala, and Hualalai.

The analyses in Table 1 pose the fundamental geochemical problem of explaining the differentiation of primitive tholeiitic magma to produce the other types of rocks with such greatly different composition. An adequate theory must not only satisfy the chemical criteria but must also correlate existing information on the relative amounts of the different types of rocks, their sequence of eruption, the melting and reaction relationships among the constituent minerals, and the kinetics of ascent and cooling of molten magmas.

All investigators of Hawaiian basalts since Cross (*15*) have emphasized the role of kinetics of eruption in controlling the extent and nature of differentiation of basaltic magma, but they have not agreed on the precise mechanism of control. Particularly, the mechanism of transition from tholeiitic to alkalic magmas during the life cycle of a volcano has remained in doubt. Our studies suggest that the transition is mainly the result of progressively more favorable conditions becoming established for extensive fractional crystallization of pyroxene during the later stages of a volcano, when magmas rise and cool very slowly and eruptions become very infrequent. This dynamical-chemical relationship is here discussed briefly with the aid of Fig. 12.

Of the many different ways in which analyses of basaltic lavas may be plotted for study, the one shown in Fig. 12 offers the great advantage of indicating the compositions of the three major minerals of the lavas—namely, pyroxene, plagioclase feldspar, and olivine. In this diagram differences in chemical composition are directly interpretable in terms of differences in the proportions of the three minerals. The diagram was originally derived by plotting the composition of 150 basaltic rocks from Hawaii and the British Hebridean province, and it has been published in full elsewhere (*22*). The skeletonized version is presented here for the sake of simplicity and clarity.

The parallelism in composition between the tholeiitic basalt series (*C-a-A-B-b-D*) and the alkalic series (*G-c-E-d-F*) is well shown in Fig. 12. Both series have olivine-rich members (*C-a-A* and *G-c*) and a group of closely related differentiates with progressively increasing content of silica (*B-b-D* and *E-d-F*). In the tholeiitic series, this group includes rocks, such as granophyre (*D*), that are rich in quartz, whereas in the alkalic series even the most siliceous member (trachyte *F*) is free of quartz but is rich in alkalic feldspar.

Molten tholeiitic magma of composition *A*, rising toward the surface, cools and first precipitates olivine [(Mg, Fe)$_2$ SiO$_4$] crystals, which grow rapidly

in size to a diameter of several millimeters (*23*). Olivine, having a greater specific gravity, tends to sink in the molten magma. This simple act of separating the crystal from the melt in which it formed changes the composition of the melt along the line *A* to *B*, and the composition of the underlying magma that receives the settling olivines, along the line *A* to *C*. Thus originate two complementary types of lavas, tholeiitic basalt (*B*) which is poorer in olivine, and picritic basalt (*C*) which is richer in olivine, than the parent magma. It should be noted that a shift in composition anywhere in the diagram involves such a fractional crystallization of one or more minerals.

There is a limit to changing the composition of the melt by settling of olivine because, at around point *B*, olivine precipitation ceases, and with decreasing temperatures augitic pyroxene [$(Ca, Mg, Fe^{2+}, Fe^{3+})$ $(Si, Al)_2O_6$] begins to crystallize. If the rate of cooling is very gradual and pyroxene is crystallized fractionally, the composition of the residual melt will move along *B-E* into the zone of the alkalic series. If the cooling is rapid, as in the currently active volcanoes, plagioclase feldspar [$(Ca, Na)(Al, Si)$ $AlSi_2O_8$] soon starts to crystallize along with pyroxene, and the fractional syncrystallization of the two minerals yields residual melts with tholeiitic compositions along *B-b-D*. Therefore, the rate of ascent and hence cooling of the magma within the temperature range of the initial crystallization of pyroxene is of utmost importance in the differentiation of basaltic magma.

The spectacular eruptions of Kilauea and Mauna Loa permit us to observe tholeiitic lavas in the making. As indicated in Fig. 12, however, only a part of the tholeiitic series is represented among the lavas of these two volcanoes. Compositions between *b-D* apparently require a somewhat slower regimen of cooling than that experienced by materials that reach the surface, and rocks with such compositions may be crystallizing at depth within the two volcanoes. In the deeply dissected Koolau Volcano on Oahu and in Tertiary volcanoes of the British Hebrides, such rocks are found characteristically as dikes, sills, and other intrusive bodies. The entire tholeiitic series of rocks, therefore, appears to be a product of conditions that prevail in basaltic volcanoes that erupt vigorously and frequently.

Kilauea and Mauna Loa erupt on the

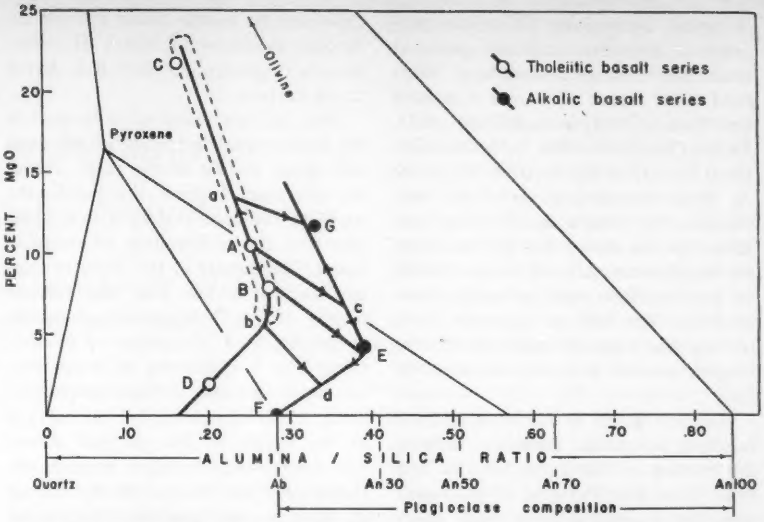

Fig. 12. Diagram showing interrelationships among typical Hawaiian volcanic rocks as manifested by their composition with respect to magnesia and alumina-silica ratio. Open circles, rocks of the tholeiitic basalt series listed in Table 1; solid circles, rocks of the alkalic basalt series. Tholeiitic olivine basalt (point *A*) is the primary magma of Hawaii; all other rock types are derived from it by fractional crystallization. The fractional crystallization of the different minerals and the resulting changes in the composition of tholeiitic and alkalic magmas are as follows: Olivine loss; *A-B* and *c-E*; olivine gain; *A-C* and *c-G*; pyroxene plus plagioclase loss; *B-b-D* and *E-d-F*; pyroxene loss; *a-G*, *A-c*, *B-E*, and *b-d*. The zone enclosed by a dashed line marks the range in composition found in tholeiitic lavas of the currently active volcanoes Kilauea and Mauna Loa.

average every few years. The reduced vigor of volcanoes that have reached the stage of producing alkalic lavas is illustrated by Hualalai on the island of Hawaii and Haleakala on the island of Maui. One hundred and sixty and about 210 years, respectively, have passed since these volcanoes last erupted (*24*). The more sluggish and halting ascent of the magma in such volcanoes allows the very slow cooling that is necessary for fractional crystallization of pyroxene.

The general derivation of alkalic magmas through fractional crystallization of pyroxene is shown in Fig. 12, starting from four illustrative points (*a*, *A*, *B*, and *b*) in the tholeiitic series. There are differences in the details of the fractional crystallization process along the four paths, but discussion of these differences will be deferred to a subsequent article. Within the alkalic series itself, the same fractional crystallization of olivine and of pyroxene and feldspar takes place as in the tholeiitic series and accounts for the parallelism in composition between the two series. In general, the olivine and pyroxene that are fractionally crystallized from the cooler alkalic magmas are richer in ferrous iron.

The world-wide problem of the origin of tholeiitic and alkalic basalts is being actively investigated by many petrologists, some of whom favor a separate derivation of the two compositional series from different depths in the mantle of the earth. Our studies suggest, rather, that the composition of basaltic rocks is primarily a function of the rate of ascent and cooling of a single fundamental magma. With the geological, geophysical, and geochemical techniques now available at the observatory located on an active volcano, it should be possible to obtain experimental verification of this interesting relationship between kinetics of eruption and composition of erupted lavas, at least within the tholeiitic basalt series.

Volcanic Gases

In Hawaii, volcanic gases are manifested most spectacularly during an eruption in the effervescing fire fountains, which squirt a pulsating stream of molten lava up to heights of a thousand feet and more. In other volcanic regions, such as Indonesia (*25*), they give rise to more explosive and deadly phenomena like *nuée ardente* eruptions.

A typical composition (in volume percent) of Hawaiian magmatic gases, as established through the work of Shepherd (*26*), Jaggar (*27*), and Naughton and Terada (*28*), is as follows: H_2O, 79.31; CO_2, 11.61; SO_2, 6.48; N_2, 1.29; H_2, 0.58; CO, 0.37; S_2, 0.24; Cl_2, 0.05; A, 0.04. The proportions of the constituents vary over a certain range, and Ellis (*29*) has shown that the variations are largely accountable in terms of shifts in gas equilibria with changing temperature. The role of gases in controlling the state of oxidation of the magma requires thorough investigation (*30*).

Volcanic gases, in whole or in part, represent primordial materials reaching the surface of the earth for the first time. Thus, over the span of geological time the accumulation of such gases from innumerable eruptions determined the evolutionary course of our atmosphere and hydrosphere. The new Geochemical Laboratory is equipped with a mass spectrometer for rapid analysis of gases, and a program of systematically analyzing all volcanic exhalations has been started.

Summary

Hawaiian volcanoes offer an unmatched opportunity for studying the mechanism of eruptions and the differentiation of primitive tholeiitic basaltic magma. They are located near the center of the Pacific basin, more than 2000 miles from the nearest region of active tectonism, and the story of their origin and continuing activity is one of pure volcanism. Because their lavas experience a minimal exposure to contamination by heterogeneous crustal rocks as they rise to the surface, fractional crystallization plays the dominant role in producing changes in the chemical composition of the lavas extruded at different stages in the life cycle of the volcanoes.

The enormous size, relatively simple structure, and frequent voluminous eruptions of Hawaiian volcanoes all permit the effective use of seismographs and tiltmeters in delineating their internal structure and in detecting the movement and accumulation of magma within them. Other more general geophysical investigations of the Pacific crust and the mantle below provide additional evidence on where Hawaiian magma originates and how it is driven to the surface.

The ultimate cause of volcanism is the fundamental instability of the crust and upper mantle of the earth. About 60 kilometers beneath the Pacific the rocks of the mantle yield a fluid fraction with the composition of tholeiitic basalt. The density of this basaltic magma fraction is less than the average density of the 50 kilometers of mantle (peridotite?), 5 kilometers of basaltic crust, and 5 kilometers of water that lie above it, and if the opportunity arises it can be squeezed to the surface by the weight of the material above. The fundamental fracture beneath the Hawaiian Ridge has tapped this source of magma and provides the avenue through which it can escape to the surface.

Lava rising through the fundamental fracture beneath Kilauea accumulates slowly in a shallow reservoir only a few kilometers beneath the caldera. At irregular intervals dikes project upward from the expanding reservoir, and if the expansion and consequent pressure within the reservoir are great enough, the dikes break through to the surface and discharge the accumulated lava in an eruption.

Geochemical studies show that while the volcanoes are vigorously active, the most striking variation in their lavas is the content of olivine. Rapid delivery of magma to the surface permits only slight cooling underground, and the only mineral that is fractionally crystallized in significant amounts is olivine, which is depleted from some flows and concentrated in others. When activity declines and magma wells up from depth much less rapidly, it remains in the shallow reservoirs for increasingly longer periods of time. Here the magma cools so slowly through the temperature range in which pyroxene crystallizes that this mineral, as well as the early-formed olivine, settles out of the melt and is immobilized on the floor of the reservoir. Such separation of pyroxene "desilicates" the tholeiitic parent magma and changes its composition to that of alkalic basalt, the predominant lava of the declining stage of Hawaiian volcanism. The temperature, composition, and rate of ascent of the basaltic magma to the surface, therefore, are closely interrelated, and the study of the complex interrelationships of these geophysical and geochemical factors constitutes the fascinating work of observing how volcanoes grow.

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Dues and Membership in Scientific Societies

Current statistics for societies reveal distinct differences among the various disciplines.

Ileen E. Stewart and Vincent W. McGurl

For over one hundred years the scientific societies of the United States have provided the principal means of communication among American scientists. In the late 1800's the first of the newly formed societies brought small groups of specialists together, usually on a local basis, for the exchange of research ideas and results. The fashion for letter writing doubtless kept individual members in touch between meetings. As membership increased and became national and even international, the society journals appeared as the logical communications media. Regular annual meetings for the oral presentation of research results were soon established and quickly became traditional. This pattern of society activity has persisted over the years and has served the scientific community well.

Recently, however, pressures have developed that have forced professional societies to reconsider their role and their methods of providing scientists with avenues of communication. One of these pressures has been the increasing number of research papers offered to society journals for publication. This increase is due in large part to the greater number of scientists at work in all fields and to the mounting financial support of research by both federal and private sources. The rising cost of printing has contributed its share, as well, to the problem.

The Office of Science Information Service of the National Science Foundation, both by its basic legislation (*1*) and by recent directives (*2*), is authorized to encourage and facilitate the dissemination of scientific information. In line with these directives the primary research journal has been receiving the attention and support of the Foundation for some time. Because the majority of the country's scientific journals are published or sponsored by professional societies, a preliminary study of these societies seemed in order. In particular, "yardstick" data on dues, membership, and journal subscription rates were needed. Consequently, in July 1959 the Foundation sent a brief questionnaire to the secretaries of 215 professional scientific societies. This is the report of that survey.

The societies included were national in scope and membership, with members who were primarily professional scientists actively engaged in research or teaching. Societies in clinical medicine and applied technology were excluded, as were Greek-letter and honorary societies and regional and state organizations. Of the 215 questionnaires mailed, 15 of those returned were ultimately rejected as inappropriate, 22 were not returned, one arrived too late for inclusion, and 177, or 82 percent, were used in the study.

Membership

For analytical purposes, societies were grouped into seven major disciplines plus a "miscellaneous" category that contained a variety of disciplines, none numerous enough to be considered separately (*3*) (Table 1).

It must be kept in mind, in considering total membership figures, that they do not take into account the multiple memberships that exist in certain fields (for example, biology) and between certain disciplines. These figures, however, do offer rough indications of the numbers of scientists in each discipline. Individual society membership ranged from less than 100 to more than 87,000.

Average membership figures clearly pointed up a well-established pattern in the field of biology—that of "splintered" interests and specialization resulting in a large number of societies (67) with relatively low average membership (1489). The social science societies showed signs of a similar situation, although not to the same degree as biology. Engineering displayed another condition—a large number of societies (35) with extremely high average membership (14,822).

Most societies offer scientists a choice of membership. Commonly, this includes senior or active membership, junior or student membership, and institutional (corporate, contributing, or sustaining) membership. Requirements for membership vary widely both between individual societies and between disciplines. Thirty-three percent of all societies surveyed required an academic degree for senior membership. Engineering was the most liberal with respect to the degree requirement—only 6 percent of the engineering societies required a degree. Chemistry, on the other hand, was most conservative—80 percent of the societies in this field required a degree for senior membership.

Age of Societies

The oldest society in the study (Table 2) was 160 years old; the youngest, one year old. Of the 176 societies (*4*) analyzed for age, 60 percent were less than 60 years old. The eight oldest societies (*5*), founded before 1860, did not include any societies in the fields of chemistry, physics, or earth science.

All disciplines were represented in the 49 societies formed since 1941. It

Table 1. Society membership by major discipline. The number of societies included in each discipline is given in parentheses.

Discipline	Membership		
	Total	Average	Median
Engineering (35)	518,781	14,822	8,807
Chemistry (10)	107,448	10,744	1,625
Biology (67)	99,774	1,489	788
Social science (22)	65,287	2,967	1,601
Physics (12)	41,168	3,430	1,120
Earth science (12)	39,246	3,270	1,201
Miscellaneous (11)	31,689	2,880	1,537
Mathematics (8)	29,839	3,729	2,634

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Table 2. Number of societies included in the study, by age.

Period of founding	Societies (No.)
1799–1860	8
1861–1880	8
1881–1900	26
1901–1920	46
1921–1940	39
1941–1959	49

was interesting to note that six, or 50 percent, of the physics societies were founded between 1941 and 1959.

An attempt was made to compare ages of societies with their total membership, but no significant correlation was found. Nor did there appear to be any correlation between the age of a society and the annual dues paid by senior members.

Annual Dues

Society dues (Table 3) varied with membership; junior or student membership, when offered, carried considerably lower dues than senior or active membership. Life membership, offered by 37 societies, usually cost between $100 and $200. Emeritus and honorary members were seldom required to pay dues. For purposes of this study, only senior membership dues figures were used in the calculations.

Comparison of Median Annual Dues and Median Annual Salaries

Since median annual salary figures for scientists in all disciplines were available from the National Register of Scientific and Technical Personnel (*6*), a comparison was made between these and median annual dues (see Fig. 1). When median salary levels were ranked by discipline, biology was lowest, with $6789, while engineering was highest, with $9065 per year. The same disciplines also had the lowest and highest dues rates, biologists paying median dues of $6 and engineers dues of $15 per year.

Income from Dues

As might be expected, senior members contributed the highest percentage of total income from annual dues (Table 4). This percentage ranged from 69 percent in chemistry to 91 percent in biology. Institutional members also provided a substantial proportion of the income from dues, and all disciplines, but not all societies, had this category of membership. The average income from this source for all disciplines was 17 percent. Of interest was the fact that social science derived the highest percentage (22 percent) of dues income from institutional

Table 3. Society dues, by discipline.

Discipline	Annual dues ($)	
	Range	Median
Biology	1–20	6
Mathematics	5–14	7.50
Earth science	2–15	8
Physics	2–25	8.75
Social science	1–25	9.50
Chemistry	2–15	10
Miscellaneous	2–20	10
Engineering	1.50–25	15

membership. Engineering followed with 20 percent, and chemistry was third with 18 percent. Earth science societies ranked lowest (10 percent) in income from this source.

The average total income that each society derived from annual dues (all categories) ranged from $12,800 per society in biology to $234,200 in engineering.

Sixty societies, or about 33 percent of the total number in the survey, reported that their sole source of income was from dues. More than half of this number were in biology.

Income from Other Sources

At least 66 percent of all societies had sources of income other than dues; percentages ranged from 50 percent for physics societies to 86 percent for the societies in social science. Other sources of income included contributions, endowments, sale of lists, books, reprints, annual meeting registration fees and exhibit space rental, investments, and advertising.

Society Journals

More than 86 percent of the societies polled in this study published at least one scientific journal as part of their service to members. A scientific journal was defined as a publication appearing at least twice a year and containing the results of original research. This definition excluded newsletters, memoirs, and annual proceedings.

Sixty-seven percent of the societies indicated that their members received at least one journal free of charge with the payment of dues. About 19 percent of the societies had more than one scientific publication, and members might be charged for all or none. Fifty percent of the chemistry societies, for example, charged their members for at least one journal.

Twenty-nine societies published no

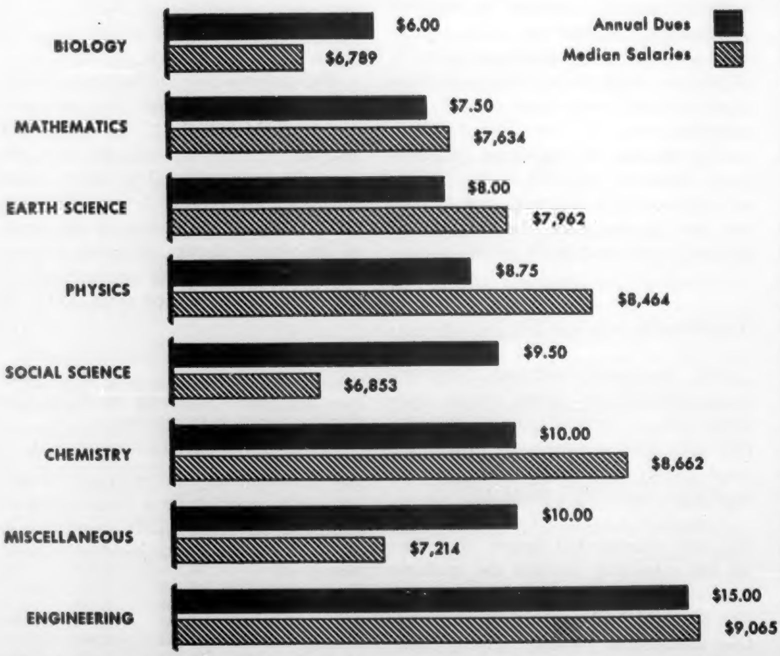

Fig. 1. Comparison of median annual dues and median annual salaries, by discipline.

research journal. Most of these were small societies; approximately half had less than 500 members. About one-third of these societies, however, did publish some form of annual proceedings. Biology, with the highest number of individual societies and almost 100,000 members, published only 0.9 of a journal per society. Mathematics, conversely, with the least number of societies and approximately 30,000 members, published almost 1.9 journals per society.

Individual journal circulation figures revealed a low of 250 and a high of 85,000. Average circulation followed a disciplinary ranking similar to that for median annual dues, with biology lowest (2635) and engineering highest (13,074) (Table 5).

A comparison of total membership and total circulation figures, by discipline, provided some interesting bases for speculation. In the fields of mathematics, physics, chemistry, and social science, the total circulation of society journals was approximately twice the total membership of the societies that produced the journals. This would appear to indicate an extensive readership outside the societies themselves and might mean either a large audience in allied fields or wide foreign distribution. It might also mean that scientists in these fields regularly receive—or read—more than one journal.

Biology fell somewhere in middle ground in this comparison, but earth science and engineering showed total membership and total circulation figures that were very nearly the same (circulation was always somewhat higher). This could be interpreted to mean that these societies include in their membership most of their journal readers. It might also mean that in these disciplines society members read fewer journals.

Table 7. Average dues of senior members in scientific societies, by discipline. Figures in parentheses represent number of societies.

Discipline	Dues ($) 1937	1948	1959
Engineering (17)	13.46 (14)	13.41	17.32
Chemistry (9)	7.07 (7)	8.87	11.83
Physics (7)	6.30 (3)	7.36	11.07
Social science (12)	6.08 (6)	6.80	9.12
Earth science (11)	5.70 (10)	5.36	8.68
Mathematics (4)	5.66	6.50	9.25
Psychology (2)	5.50	5.50	13.00
Biology (41)	3.62 (37)	4.68	9.12

Table 4. Relation of membership dues and institutional dues to total annual dues, by discipline, and number of societies whose total income is from dues. The number of societies included in each discipline is given in parentheses.

Discipline	Societies with senior members: No.	Av. % of dues paid by senior members	Societies with institutional members: No.	Av. % of dues paid by institutional members	Range (%)	Societies receiving income only from dues (all categories) (No.)
Chemistry (10)	9	69	4	18	10–31	2
Engineering (35)	35	73	15	20	2–57	9
Social science (22)	22	70	7	22	3–32	3
Biology (67)	67	91	21	15	1–46	31
Mathematics (8)	8	85	5	16	9–30	3
Earth science (12)	12	85	3	10	2–23	3
Physics (12)	12	88	6	15	1–33	6
Miscellaneous (11)	11	76	8	21	4–45	3

Table 5. Membership, numbers of journals, and journal circulation, by discipline.

Discipline	Societies (No.)	Total membership	Journals (No.)	Circulation: Total	Circulation: Av.
Biology	67	99,774	60	158,141	2,635
Social science	22	65,287	31	130,437	4,207
Earth science	12	39,246	11	48,619	4,419
Mathematics	8	29,838	15	68,410	4,560
Physics	12	41,168	14	93,092	6,649
Miscellaneous	11	31,689	14	137,560*	9,925
Chemistry	10	107,448	15	187,860	12,524
Engineering	35	518,781	43	562,199	13,074

* Includes the 85,000 circulation of *American Scientist*, of which Sigma Xi, a society not included in this survey, is one of the publishers.

Table 6. Total and average membership in scientific societies, by discipline. The number of societies included in each discipline is given in parentheses.

Discipline	1937 Total	1937 Av.	1948 Total	1948 Av.	1959 Total	1959 Av.
Engineering (11)	62,337	5,667	74,251	6,750	228,651	20,786
Biology (28)	22,800	814	35,265	1,259	61,245	2,187
Chemistry (4)	22,198	5,549	54,529	13,632	93,505	23,376
Earth science (8)	11,870	1,483	32,007	4,000	65,738	8,217
Mathematics (3)	5,990	1,997	10,385	3,461	21,513	7,171
Physics (4)	3,899	974	9,514	2,378	22,381	5,575
Social science (5)	2,904	580	4,276	855	13,933	2,786
Psychology (2)	2,180	1,090	5,134	2,567	17,528	8,764

Annual Meetings

Ninety-four percent of all societies sponsored annual meetings at which original research papers were presented. Approximately 70 percent indicated that at least some of these papers were subsequently published either in the society journal or in some other appropriate publication. No society supplied figures on the exact number of papers ultimately published. Some information is available, however, from other sources (*7*), on the percentage of meeting and conference papers that eventually appear in print.

Trends in Society Membership

It seemed highly desirable to measure, if possible, the recent growth of professional societies. To obtain information about past dues, total membership figures, and journal subscriptions, the third (1937) and the fifth (1948) editions of the *Handbook of Scientific and Technical Societies and Institutions of the United States and Canada* (*8*) were searched. Not all 177 societies that responded to the National Science Foundation questionnaire appeared in these early National Academy of Sciences–National Research Council volumes, and in many cases information was incomplete in certain categories. Sixty-five societies did appear, however, in both the 1937 and 1948 volumes.

Figures collected from these sources showed that during the period 1937–

Table 8. Summary of average journal costs in 1937, 1948, and 1959 and percentage increases, in nine disciplines. The number of journals included in each category is given in parentheses. Blank spaces indicate that no data were available.

Discipline	Av. cost of journal to members ($)			Increase (%)			Av. cost of journal to nonmembers ($)			Increase (%)		
	1937	1948	1959	1937–48	1948–59	1937–59	1937	1948	1959	1937–48	1948–59	1937–59
Physics (8)		8.19	20.81		154			8.00	18.06		125	
Chemistry (7)*	10.90	10.80	17.78	−1	63	64	7.20	6.90	16.14	−4	133	124
Mathematics (5)		10.30	17.40		69			9.40	20.60		119	
Meteorology (2)		10.00	19.00		90			4.75	12.00		152	
Earth science (5)*	5.40	5.80	9.60	7	66	77	6.14	7.40	12.60	20	70	105
Psychology (9)*	5.20	5.94	23.72	14	299	356	4.60	5.94	9.77	29	64	112
Social science (7)		7.07	11.07		56			4.85	8.70		79	
Engineering (7)†	13.50	13.85	21.64	2	56	60	7.50	8.25	10.57	10	28	41
Biology (27)‡	5.10	5.60	10.40	10	86	104	5.30	5.90	12.50	11	112	135

* Data for 1937 were based on five journals. † Data for 1937 were based on four journals. ‡ Data for 1937 were based on 18 journals.

1959 all disciplines experienced a substantial increase in society membership. In 1937, engineering (5667) and chemistry (5549) had the highest average society membership; social science (580) and biology (814) had the lowest. By 1959, both chemistry (23,376) and engineering (20,786) had quadrupled their average membership. Social science (2786) and biology (2187) were still lowest (see Table 6) but had made substantial gains.

Trends in Society Dues

The dues paid by senior members increased in all disciplines during the period 1937–1959 (see Table 7). Between 1937 and 1948 a relatively small increase occurred; the average rise was about 16 percent. During the next 11-year period the increase was more pronounced: the average, except for psychology, was about 56 percent. The average dues for psychology were somewhat out of line because of a very large increase in dues in one society between 1948 and 1959.

The range of average dues for senior members extended from $3.62 in biology to $13.46 in engineering in 1937. By 1959 the range was somewhat shorter and extended from $8.68 for earth science to $17.32 for engineering.

Trends in Costs of Journals to Members and Nonmembers

From the same sources of data for 1937 and 1948 (*8*), the costs, to members and nonmembers, of 75 journals were obtained. Table 8 summarizes the average journal costs in 1937, 1948, and 1959 and the percentage increases for nine disciplines. Costs to members were based on senior member dues plus the additional amount (if any) that members were required to pay for a subscription. This base line for comparison was chosen as the only possible one, although it was realized that some unknown proportion of member dues was allocated to general society services. The figures for cost of journals to members are, therefore, somewhat on the high side. With one exception the average dollar cost of journals to members followed a pattern similar to that of dues—a slight rise during the 1937–1948 period and an abrupt rise from 1948 to 1959. The only discipline at variance was chemistry, which actually dropped from $10.90 to $10.80 during the period 1937–1948. The increase in average journal costs to members from 1948 to 1959 ranged from $3.80 in earth science to almost $18 in psychology.

Journal costs to nonmembers followed a similar trend—a slight rise from 1937 to 1948 and an abrupt one from 1948 to 1959. Again, the one exception was chemistry for the 1937–1948 period. The actual average dollar increase for nonmembers was less than for members, ranging from $2.32 for engineering to more than $11 for mathematics during the period 1948–1959.

These data, interesting as they are, offer only a limited picture of the national journal situation. The National Science Foundation intentionally asked few questions about journals in its society questionnaire because a separate, comprehensive survey of research journals was being planned. This journal study is now well underway, and a report can be expected in early 1961. Both studies form part of a general fact-finding program that the Office of Science Information Service of the Foundation is undertaking. Studies in progress or planned include the publication "climate" in industry (being made jointly with the Office of Special Studies; report expected in 1960); publication of symposia and conference proceedings; the role of monographs in communications; and the status of commercially published research journals.

References and Notes

1. National Science Foundation Act, 1950, as amended.
2. Title IX of the National Defense Education Act (1958), sect. 10. Executive Order 10521, 17 March 1954, added by Executive Order 10807, 13 March 1959.
3. Societies included in the "miscellaneous" category were as follows: American Nuclear Society, American Academy of Arts and Sciences, American Meteorological Society, American Astronomical Society, Astronomical Society of the Pacific, Human Factors Society, American Ceramic Society, Arctic Institute, American Documentation Institute, Institute of Navigation, and Scientific Research Society of America.
4. The age of one society could not be determined.
5. The eight oldest societies were as follows: American Academy of Arts and Sciences, founded 1780; American Physiological Society, founded 1799; American Statistical Association, founded 1839; American Ethnological Society, founded 1842; American Pomological Society, founded 1848; American Society of Civil Engineers, founded 1852; American Geographical Society, founded 1852; and American Entomological Society, founded 1859.
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Science in the News

Atoms for Peace: An American Victory of Uncertain Value Is Won at the Vienna IAEA Conference

The United States position on the necessity for safeguards and controls on fissionable material distributed through the International Atomic Energy Agency was upheld at Vienna last week, but the proposal had to be pushed through over the objections of India and five other neutral Asian nations as well as those of the Soviet bloc.

The issue was not a new one. President Eisenhower had spoken of a need for safeguards when he made the atoms-for-peace proposal which led to the establishment of the IAEA. Three years later, the original agreement setting up the agency spoke of a system of safeguards to make sure, or at least reasonably sure, that fissionable material distributed through the agency would not be used for military purposes. But a detailed operating plan for the safeguards took several years for an agency committee to work out, and a safeguards system was never put into operation in the IAEA.

As a result, the agency has never assumed what was to be its primary function of distributing nuclear material. The United States, instead, has bypassed the agency and worked through bilateral agreements with the various countries which have included arrangements for safeguards whenever fissionable quantities of radioactive materials have been involved. This year, though, a draft proposal for safeguards procedure was ready, and the United States successfully pressed for a resolution endorsing, in general terms, its adoption. The details are to be fixed by the IAEA's permanent organization and are to be subject to changes based on technological development. The plan includes such things as audits of fissionable material, operating reports, and on-the-spot inspections.

The American move was strongly supported by Great Britain, Japan, and a majority of the other members of the agency. It was opposed by a group of neutralists, headed by India; by the Soviet bloc; and by the Union of South Africa. The value of the American victory is uncertain, for unless the cooperation of the opposing powers can be won the safeguards system will be of little significance.

The Union of South Africa remains free to sell uranium ore directly to nations which want it, without working through the IAEA. The Soviet Union is similarly unencumbered. If these nations are willing to sell nuclear material through bilateral agreements without safeguards, then India and other nations objecting to safeguards can, of course, avoid them. Yet the central reason for the United States' taking the lead in organizing the IAEA was the hope that an effective system of international controls and inspection could be established through the agency, both to discourage the spread of atomic weapons and to make at least a beginning toward a system of general controls and inspection that might lead to some progress on the problem of arms control.

United States Position

At the time the IAEA was organized the State Department told Congress that without an international control agency "the U.S.S.R. would have a strong incentive to seek adherents through nuclear aid 'with no strings attached'—i.e., without inspections and controls. In other countries commercial suppliers would exert pressure on their government to allow them to export nuclear materials and equipment under the least onerous conditions. Thus without the IAEA the erosion of control criteria would eventually tend to place any reasonably advanced country in a position to create weapons."

The State Department also pointed out that the control sections of our bilateral agreements would be more palatable to other countries if the controls reflect an internationally accepted approach rather than something imposed unilaterally by the United States. The hope was that the IAEA would assume a broker's function in facilitating and keeping track of all international exchanges of nuclear materials.

The adoption of the American resolution in Vienna last week will help on the American interest in controls: it will make controls more palatable to the countries receiving nuclear material from the United States by making the controls internationally agreed upon rather than American-imposed. We have suggested to the 50-odd nations with which the U.S. has bilateral agreements that these be transformed into arrangements working through IAEA once the international safeguards system is in operation. But the larger aim of establishing a control system with all nations working through the international agency has not been moved forward very far through the adoption of a system which a number of key nations apparently intend to circumvent. The action at Vienna was an accomplishment in principle; it may or may not have laid the basis for an accomplishment in fact in future years.

Summary of Debate

The argument of India and other neutralists was that the United States wanted to impose safeguards and controls on the smaller underdeveloped powers, while the major atomic powers, which really need to be controlled, are left free of controls. The American answer has been that you have to start with controls somewhere, and that the limited control system under the IAEA is a first step, indeed the only step toward controls that seems realistically attainable at this time. The Indians were unconvinced, though, and continued to argue that the controls are a one-sided infringement of sovereignty. The United States offered voluntarily to place four American reactors under the control system. This was only a token move, of course, since the four controlled reactors would be only a small part of American nuclear facilities. But as a gesture to show that the United States is willing to accept controls on itself as well as to impose controls on others, the move, made by Atomic Energy Chairman John McCone, strengthened the American position.

Meanwhile, the Russians enthusiastically supported the neutralists. They

repeated the arguments that the controls are one-sided, an infringement on national sovereignty, a guard over those who least need guarding, and unlikely anyway to prevent a determined nation from building an atomic bomb. The Russians, echoing the mood of Mr. Khrushchev at the United Nations, suggested that the whole control idea is another plot of the American monopolists who want inspections and safeguards so that they can steal the information developed by researchers in underdeveloped countries.

The conference, in general, was turned into a miniature of the debate at the United Nations. The Soviet bloc introduced resolutions on disarmament and the test ban. As in the past, the United States took the position that these are extraneous issues. We argued that, meritorious as the Soviet bloc resolutions might or might not be, to accept them would merely subvert the purpose of the IAEA, which is not likely to accomplish much if the Russians are allowed to turn the organization into a propaganda forum by talking about and passing resolutions on subjects which are beyond the scope of the agency.

There was more political bickering over the question of admitting Communist China to membership. The American position, in effect that Communist China should not be admitted until after it has been admitted to the U.N., was upheld, but by a smaller margin than last year.

Accomplishments of the IAEA

Sterling Cole, the former chairman of the Joint Congressional Atomic Energy Committee who has headed the IAEA since its organization, pronounced the agency's activities "modestly successful" in its first three years. He mentioned the agency's sponsorship of fellowships, international scientific conferences, and its work on international health and safety standards. He spoke of the usefulness of agency survey teams in helping underdeveloped countries work out realistic plans for using atomic energy, a part of the agency's activities for which the United States has special reason to be grateful. For the high hopes of what could be accomplished through atomic energy programs that were implicit in Eisenhower's 1953 atoms-for-peace speech, and which continued in U.S. pronouncements for two more years, have been sadly deflated. It has been convenient that an international agency has taken the responsibility for scaling down the dreamlike expectations of atomic wonders. Otherwise this awkward task would have had to be undertaken by representatives of the American government, which contributed so enthusiastically to raising the now deflated hopes.

As things are, the realization that cheap atomic power is probably still quite a few years off has not reacted against the United States, for the over-optimism was general, and the United States is not being blamed for sharing in it and thus being led in the early years to suggest that underdeveloped nations could expect much more from the atoms-for-peace program than it has turned out to be capable of delivering. Despite the drastic reappraisal of what could be expected of atomic energy in the near future, the atoms-for-peace plan seems to be a plus for the United States, for the proposal made a fine impression on the rest of the world, even if, so far, it has never come to much.

There is a general feeling that Sterling Cole was justified in calling the IAEA, the organization developed to implement the atoms-for-peace proposal, modestly successful. It has been a useful organization, despite the tendency of its general meetings to become bogged down in futile political debate. Despite the strong reaction to the overblown hopes of the earlier '50's ("These people don't need a reactor. What they need is a plow!") there is still room for a good deal of work, particularly in the less spectacular area involving the use of radioisotopes, where, in contrast to nuclear power, the feeling is that more useful work could be done than is being done for the underdeveloped countries.

The American budget for atoms-for-peace, despite the wide publicity given the plan, is very small, although still much larger than that of any other country. It includes something over $5 million a year for our contribution (32 percent) to the assessed budget of IAEA. But in the area of specifically American work, the lone item in this year's mutual security appropriation called for only $3.4 million, less than 0.1 percent of our total foreign-aid appropriations. This modest figure was cut by 60 percent, to only $1.5 million, by the House Appropriations Committee, and the State Department made no strong effort to have the money restored by the Senate. The budget has thus dwindled to a point where it can only go up in future years, unless the program is simply dropped, something which does not seem likely.

Patent Medicines: A Modest Drive Is Underway to Educate the Public

Last week the American Medical Association began work on an effort to educate the public on how much money it is wasting on worthless nonprescription medicines. The Food and Drug Administration and consumer organizations have been involved in similar educational efforts, but the public has not seemed much interested, although the value of worthless nonprescription drugs sold is usually estimated in terms of hundreds of millions of dollars per year. The AMA estimates the average spending per family at over $200 a year on proprietary medicines, most of them harmless, but a waste of money. The point of the AMA's drive is to suggest that there are better ways to attack the problem of high medical costs than to get the federal government involved in paying for medical care.

The grosser abuses of the patent medicine business were largely eliminated years ago through government regulations. The principal issue today is the problem of what Food and Drug officials refer to as "mere economic fraud." The FDA says it does not have the budget and staff to worry about cases of mere fraud, where no real danger to health is involved. It contents itself with occasional speeches by its officials and with a few pamphlets and press releases, none of which receive anything like the circulation of the proprietary drug advertising they are intended to counteract.

The Federal Trade Commission, on the other hand, does get involved in cases of fraud, but its powers are limited. (It required nearly 20 years of litigation for the FTC to get the makers of Carter's Pills, an ordinary laxative, to stop claiming that the pills would produce wonderful effects by stimulating the flow of liver bile.) In effect, the FTC has the power to stop advertising that is clearly untrue. It cannot do anything much about advertising which, while it may be literally true, is plainly intended to mislead the public. —H.M.

News Notes

Pugwash Conferences Not Eaton's, American Scientists Explain; Name Change To Be Proposed

The Pugwash Conference of Scientists that is to be held in Moscow in November was discussed in an interview last month by industrialist Cyrus Eaton, and a report by United Press International that quotes Eaton as having made both proprietary and misleading remarks has led the three American members of the conference's International Continuing Committee to issue a letter of correction. The letter, which appeared in the 24 September Washington, D.C., *Post and Times Herald*, was signed by Harrison Brown of California Institute of Technology, Bentley Glass of Johns Hopkins University, and Eugene Rabinowitch of the University of Illinois. It said:

". . . The conferences to which the story refers are not 'Mr. Eaton's Conferences'; they have been initiated by scientists, and are planned, organized, and directed by an international committee of three Americans, three British, and three Soviet scientists. After Bertrand Russell had launched, in 1955, an appeal to the scientists of the world to meet and discuss the implications of science for the future of mankind—an appeal signed by Albert Einstein just before his death, and by several other outstanding scientists from many countries—Mr. Eaton offered hospitality for such a meeting at his estate in Pugwash, Nova Scotia. It was held there in July, 1957, and was followed by a series of four other meetings in 1958–1960, held in Austria and Canada. These conferences dealt with the dangers of scientific war, disarmament, world security, international cooperation of scientists, and their responsibilities to mankind.

"The so-called Vienna Declaration of September 1958 summarized the unanimously held opinions on these subjects of 80 participants at the Kitzbuhel Conference, in which scientists of widely different national and political backgrounds took part. Other conferences were devoted primarily to a frank exchange of ideas, without an attempt to reach agreement, and no conference has issued public statements endorsing or protesting any specific policies—except for support, given in the Vienna Declaration, to the conclusion of an agreement on properly controlled cessation of nuclear weapons tests—which is the official policy of all major governments in the world.

"Mr. Eaton generously accepted the costs of three out of five conferences held to date, and the organizers and participants owe him gratitude for having been a generous host, without attempting to influence the composition, program, and conclusions of the conferences. However, as Mr. Eaton has come to play an increasingly active and controversial role in political affairs, the scientists felt that his exclusive support of their conferences may place them in the wrong light. The Continuing Committee therefore solicited and obtained the greater part of funds for the conference in Kitzbuhel in September, 1959, from other individuals and foundations, and did not ask for support from Mr. Eaton in the organization of the Conference in Baden, Austria, in September, 1959 (except for secretarial assistance in the preparation and distribution of the conference papers). The Committee declined even this kind of technical support for the forthcoming Moscow Conference.

"In memory of our first meeting in Pugwash, the name 'Pugwash Conference' has been used in the subsequent conferences. It has become widely known in America, Europe, and the Soviet Union as designating a spontaneous, independent, and nonpartisan activity of scientists concerned with the survival of mankind in the atomic age. For this reason, the Continuing Committee has been reluctant to suggest a change in the name of the Conferences, despite possible misleading connotations, and confusion with other conferences organized by Mr. Eaton in Pugwash.

Name Change Proposal; Clarifications

"The public misunderstanding of our conferences as being initiated, sponsored, financed, directed or influenced by Mr. Eaton, and Mr. Eaton's own reference to them as such in correspondence and public statements, forces us to make this clarification. The Committee intends to propose to the Moscow Conference the adoption of a new name, which would avoid future misunderstanding.

"We are sorry that an encouraging cooperation between a generous business man, eager to assist the scientists of the world in their efforts to prevent the misuse of science for the destruction of mankind, and to further its use for constructive purposes, has been made impossible by his reluctance to keep his support of the scientists' conferences clearly separated from his increasing involvement. We retain our gratitude to Mr. Eaton for his original support, and would welcome him, together with our other supporters, as our guests at the Moscow Conference; but we must make it unmistakedly clear that Mr. Eaton's role in this and any future meetings can be only that of one of our guests, and not of a sponsor or active participant.

"We would like to correct also the statement by Mr. Eaton that the Conference is being held in Moscow because holding it in America was made impossible by the refusal of the State Department to admit Chinese participants. The possibility of holding a conference in the United States never yet has been explored by the Committee. Soviet scientists have offered to hold the next meeting in the Soviet Union, after five preceding ones had been held in the countries of the West; the American members of the Committee sincerely hope to be able to reciprocate by inviting our colleagues to assemble next time in the United States."

Test Ban Talks Resume without Bluster, But without Much Optimism

The Geneva negotiations on nuclear testing resumed last week after a 5-week recess. At the end of the week all was quiet and amicable, quite in contrast to the situation either at the U.N. or at the Vienna conference reported above. But there was nevertheless little hope that an agreement was likely to be reached with any speed.

On the Russian side, the Soviet behavior at the U.N. left little hope that Russians at Geneva are at all likely to make concessions that they had been unwilling to make in the rosy days before the summit collapse.

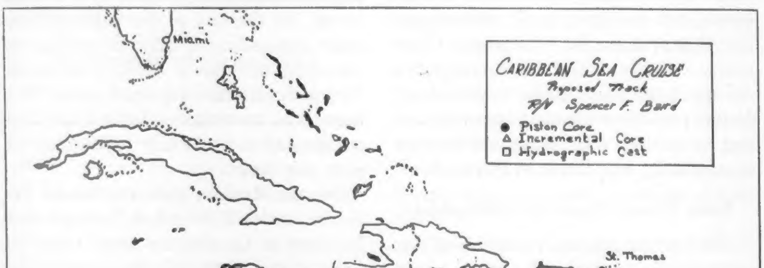
On the American side, sentiment has been rising against the ban, and particularly against trusting the Russians to obey any agreement in the absence of enforceable controls far stricter than any that can possibly come out of Geneva. This can hardly fail to make the Administration aware of the potential awkwardness of signing a treaty which the Senate might well refuse to ratify, indeed, which might not even command the support of the new Administration.

Cooperative Caribbean Expedition Launched

An expedition to the Caribbean Sea will be carried out by scientists of the Marine Laboratory, University of Miami, and of the Scripps Institution of Oceanography, University of California, during the months of October, November, and December. The Scripps Institution's research vessel, the *Spencer F. Baird,* will be used to collect geological, biological, and oceanographic information from selected areas.

The program will be primarily a geological investigation, designed specifically for collecting long piston cores from areas that may provide a fairly complete stratigraphic record of the Pleistocene. A second, important phase of this program is the completion of a hydrographic cross section of the eastern Caribbean. These studies form a portion of the more extensive program instituted by the Marine Laboratory for studying tropical oceanographic phenomena and the changes that may have occurred with varied climatic events in the past.

The proposed program includes piston- and gravity-coring with precise bathymetric control, hydrographic studies through water sampling and bathythermographic measurements, plankton-distribution studies in the upper 200 meters, studies of the chemical properties of the water, and measurements of the vertical distribution of radium near the sea floor. Gene A. Rusnak, research assistant professor of marine geology, is scientific leader of the expedition, which is supported by contracts with the Office of Naval Research and the National Science Foundation.



Proposed track of the Caribbean Sea cruise.

AEC Offers Health Physics Training Programs for State Representatives

The Atomic Energy Commission will offer intensive courses in health physics for representatives of state and local governments as a step in encouraging the states to assume control of certain radioactive materials under an amendment to the Atomic Energy Act, passed in September 1959. This instruction will provide work experience for persons who will be concerned with licensing and inspection functions in their respective states.

The commission's Health and Safety Laboratory in New York will begin a 10-week course in health physics on 17 October and will repeat the course in February of 1961. Argonne National Laboratory, Argonne, Ill., expects to offer the course early in 1961.

Similar instruction will be provided at Oak Ridge, Tenn. The Oak Ridge Institute of Nuclear Studies will offer a 4-week course in radioisotope techniques, starting 9 January 1961 and again on 6 March 1961. This will be followed by a 6-week course in health physics at Oak Ridge National Laboratory, beginning 4 April 1961.

There is no tuition charge, but persons attending, or their states, will be responsible for living expenses. Applicants should have a bachelor's degree in science or engineering, or its equivalent. The sponsoring laboratories will provide enrollment information.

Two Other Programs Offered

The AEC provides two other types of instruction for state-employed personnel.

The first is a 1-year course in radiation control, consisting of an academic year at the University of Michigan or Harvard University, followed by 3 months of on-the-job training in AEC facilities. The commission pays tuition and all laboratory fees for students accepted for this course. Applicants should have a bachelor's degree, with adequate preparation in science, preferably including mathematics through calculus. However, public-health majors who may not fully meet these academic criteria will be considered.

The second instruction plan offers on-the-job orientation and work experience in the AEC licensing and regulation programs to representatives of states planning to assume regulatory responsibility for specified radioactive materials. This program will include a 2- to 3-week period of orientation for key administrative personnel of state regulatory authorities with AEC licensing, inspection, and compliance functions; the training will be given both at AEC headquarters in Germantown, Md., and at an AEC operations office. There will also be 4 to 8 weeks of on-the-job work experience for technically qualified personnel, in licensing functions at AEC headquarters and in inspection functions at an AEC operations office.

Information about the courses at the University of Michigan and at Harvard University may be obtained from Oak Ridge Institute of Nuclear Studies or from the commission's Office of Health and Safety, Washington 25, D.C. Arrangements for on-the-job orientation and training may be made through the State-AEC Relations Branch, Office of Health and Safety, U.S. Atomic Energy Commission, Washington 25, D.C.

News Briefs

Mental health budget. Shortly before adjournment, the Congress voted $100,900,000 for the National Institute of Mental Health for the coming year. The increase of approximately $33 million over the Administration budget figure is by far the largest ever received by the institute. It is also much greater than the increases voted to any of the other components of the National Institutes of Health.

* * *

What encourages graduate study? The National Science Foundation has made a $50,000 research grant to the National Merit Scholarship Corporation (Evanston, Ill.) for a 2-year study of the various kinds of influence which different types of colleges have in stimulating their students to undertake graduate study.

* * *

Plant taxonomy research. Raymond C. Jackson, of the department of botany, University of Kansas, Lawrence, is establishing a card file on all research problems in plant taxonomy under investigation in North America. Botanists involved in taxonomy work are earnestly requested to support this project, which is under the sponsorship of the American Society of Plant Taxonomists, by sending Jackson information on current research. Such information should include a brief description of each project, the names of those conducting the investigations, and the sources of research support. The object of the file is to eliminate duplication of taxonomic effort and to foster cooperation between those working on a common problem from different approaches.

* * *

M.I.T. theses, 1958-59. Publication of abstracts of the 188 theses accepted for the doctor's degree at Massachusetts Institute of Technology in the 1958–59 academic year has been announced by the M.I.T. Office of Publications, which has copies available at $3.50 each.

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Hemophilic dogs. A new research laboratory for the study of abnormalities of the blood, primarily in a unique colony of hemophilic dogs—the only such colony known—was dedicated by the University of North Carolina School of Medicine on 25 September. The new unit has been named the Francis Owen Blood Research Laboratory.

Grants, Fellowships, and Awards

Atomic energy. The general advisory committee to the U.S. Atomic Energy Commission is now receiving nominations for the 1961 Ernest Orlando Lawrence Awards, which are presented by the AEC upon recommendation from the committee. The awards are for recent especially meritorious contributions to the development, use, or control of atomic energy in areas of all the sciences related to atomic energy, including medicine and engineering. The awards are made to no more than five recipients in any one year in the amount of not less than $5000 each, and the total amount in any one year is not to exceed $25,000. Nominees must be United States citizens, and must not have passed their 46th birthday by 1 July 1961. Nominations should be received before *1 November* by the Chairman, General Advisory Committee, U.S. Atomic Energy Commission, Post Office Box 3528, Washington 7, D.C.

Conservation. The National Wildlife Federation and its state affiliates offer a number of scholarships and fellowships for study in the field of conservation education. An applicant need not necessarily be enrolled at an institution of higher learning if his project or proposal has merit. Application blanks and further information may be obtained from: Executive Director, National Wildlife Federation, 1412 16th St., NW, Washington 6, D.C. Completed application forms must be postmarked on or before *1 November*.

Fulbright. The Institute of International Education reminds prospective applicants that forms must be filed *by 1 November* for some 800 Fulbright scholarships for graduate study or research in 30 countries. Requests for application forms must be postmarked before 15 October.

Inter-American Cultural Convention awards for study in 17 Latin-American countries have the same deadlines as given above.

Recipients of Fulbright awards for study in Europe, Latin America, and the Asia-Pacific area will receive tuition, maintenance, and round-trip travel allowances. The IACC scholarships cover transportation, tuition, and partial maintenance costs. The IIE (1 E. 67th St., New York 21) administers both of these student programs for the U.S. Department of State.

General eligibility requirements for both categories of awards are U.S. citizenship at the time of application, a bachelor's degree or its equivalent by 1961, knowledge of the language of the host country, and good health. Preference is given to applicants under 35 years of age who have not previously lived or studied abroad.

Medical education. An Alan Gregg travel fellowship in medical education will be awarded by the China Medical Board of New York, Inc., to enable a full-time faculty member of a United States medical school to undertake study in the Far East that will increase his effectiveness as a medical educator. The fellowship will provide for study and travel expenses and will include a stipend of an amount to be decided by the award committee.

An applicant must be a citizen of the United States and at least 30 years of age and not more than 55 years of age when the proposed project is due to start. Further, the applicant must, in general, be willing to devote a minimum of 4 months, full time, to the study project (maximum period 12 months) and spend a significant amount of time in one place. Applications for the 1961 fellowship should be submitted *before 15 December* to the Director, China Medical Board of New York, Inc., 30 E. 60th St., New York 22, N.Y.

Scientists in the News

Five Soviet scientists engaged in cancer research arrived 26 September for an exchange visit at the Public Health Service's National Cancer Institute in Bethesda, Md. The group included **Nicolai Blokhin**, president of the U.S.S.R. Academy of Medical Sciences and director of the Institute of Experimental Pathology and Therapy of Cancer; **L. F. Larionov**, head of the laboratory of experimental chemotherapy in the Institute of Experimental Clinical Oncology; **L. A. Zil'ber**, scientific director of the Gamalei Institute of Epidemiology and Microbiology and director of the department of immunology and malignant tumors; **M. M. Mayevsky**, head of the laboratory of experimental biotherapy in the Institute of Experimental Pathology and Therapy of Cancer; and **V. V. Gorodilova**, acting director of the P. A. Gertzen Central Institute of Oncology and head of the laboratory of virology.

Kenneth S. Pitzer, professor of chemistry at the University of California, Berkeley, and chairman of the university's coordinating council for atomic energy projects, has been elected chairman of the general advisory committee to the Atomic Energy Commission. This committee is comprised of nine members who are appointed from civilian life by the President for 6-year terms. Pitzer was elected chairman upon the retirement of **Warren C. Johnson**, vice president of the University of Chicago.

Allen Hynek has been named chairman of the astronomy department at Northwestern University and director of the school's Dearborn Observatory. Since 1956 Hynek has directed (i) the national program of optical tracking of U.S. and Russian satellites from 12 new observatories around the world, (ii) the volunteer Moonwatch program, and (iii) the computation and analysis of orbits. With Hynek at Northwestern is associate professor **Karl G. Henize**, who was in immediate charge of the 12 world-wide observatories.

The two men have announced a new program in research and education in astronomy at Northwestern. The department has not been at full strength since 1958, when former chairman Kaj Strand left to assume charge of the U.S. Naval Observatory's astrometry and astrophysics division.

Kenneth V. Thimann, professor of biology at Harvard University, has been named foreign member of the Accademia Nazionale dei Lincei, Rome, Italy, for his fundamental contributions to plant physiology, with particular reference to his studies of plant hormones.

Columbia University has appointed **Robert A. Gross** professor of engineering science in mechanical engineering, a newly created title. Gross joined the Columbia staff after 7 years as chief research scientist at the Fairchild Engine and Airplane Company on Long Island. During the 1959–60 academic year he was awarded a National Science Foundation senior postdoctoral fellowship for study at the University of California, Berkeley.

Raymond Ewell, vice chancellor for research at the University of Buffalo, has gone to India for 4 months to serve as consultant to the Government of India on the fertilizer industry, under the auspices of the Ford Foundation.

H. P. Leighly, Jr., has joined the faculty of the Missouri School of Mines and Metallurgy as associate professor of metallurgical engineering. Leighly has been serving as metallurgist at the Denver Research Institute and has been in charge of instruction in metallurgy at the University of Denver.

Myron S. Silverman, a supervisory bacteriologist at the U.S. Naval Radiological Defense Laboratory in San Francisco, has received a special research fellowship from the National Cancer Institute and will start a year's leave of absence from the laboratory in November to work on tissue transplantation and cancer immunity with P. A. Gorer, head of the department of pathology at Guy's Hospital Medical School, London.

M. W. Thring of the department of fuel technology and chemical engineering at the University of Sheffield, will arrive from England in November to conduct a course in pilot plants, models, and scale-up in chemical engineering at the Humble Oil and Refining Company, Baytown, Tex.

The training program for anesthesiology at the University of Washington School of Medicine (Seattle) was recently given departmental status and is to be headed by **John J. Bonica**, former director of anesthesiology at Tacoma General Hospital and Pierce County Hospital.

Also in the medical school, **J. Thomas Grayston** has been appointed professor of public health and preventive medicine and executive officer of the department. An authority on infectious diseases, he has headed a U.S. Navy medical research unit in Taipei, Formosa, for the past 3 years. During that period he was on leave from a position as assistant professor of preventive medicine at the University of Chicago School of Medicine.

Gilbert W. King was recently appointed associate director of research for systems and engineering at the Yorktown Research Center, International Business Machines Corporation, Yorktown Heights, N.Y. King, who joined IBM in 1958 after service with Arthur D. Little, Inc., and International Telemeter Corporation, has been serving as manager of the lexical processing research department, directing all programs in automatic language translation and information retrieval.

Joseph A. Wells, professor of pharmacology at the Northwestern University Medical School, Chicago, has been named chairman of the school's pharmacology department.

Howard P. Jenerick, executive secretary of the physiology, developmental biology, and physical biology training committees, Division of General Medical Sciences, National Institutes of Health, has left NIH to become associate professor of physiology, and to conduct independent research, at Emory University School of Medicine.

Robert E. Wilson, for the past 3 years aeroballistics program chief at the Naval Ordnance Laboratory, Silver Spring, Md., has been appointed the laboratory's associate technical director for aeroballistics. He replaces **Hermann H. Kurzweg**, who has been named assistant director of research at the National Aeronautics and Space Administration.

The surgeon general of the U.S. Air Force has announced the appointment of **Richard D. Mudd** as national consultant in occupational medicine. At present Mudd is medical director of the Chevrolet-Grey Iron Foundry, Saginaw, Mich.

Recent Deaths

Alberto E. Sagastume Berra, La Plata, Argentina; 55; professor of mathematics at La Plata University and a member of the Argentine Academy of Sciences; noted for his contributions to abstract algebra; author of *Introduction to Higher Mathematics* and *Lectures on Modern Algebra*; 11 Aug.

Wendell C. Lawther, Scranton, Pa.; 49; head of the department of physics at Keystone Junior College, La Plume, Pa.; 22 Sept.

Eugene R. Manning, Morristown, Pa.; 70; chemist for the Sun Oil Company for 18 years until his retirement in 1955, when he began teaching chemistry at the Pottsville center of Pennsylvania State University; 17 Sept.

B. Aubrey Schneider, Bergenfield, N.J.; 48; assistant director of the American Cancer Society's statistical research section; 22 Sept.

Carlile P. Winslow, Washington, D.C.; 76; director of the forest-products laboratory of the U.S. Forest Service, Madison, Wis., from 1917 until his retirement in 1946; 24 Sept.

Book Reviews

Agricultural Policy, Politics, and the Public. (*Annals* of the American Academy of Political and Social Science, vol. 330, September 1960) Charles M. Hardin, Ed. American Academy of Political and Social Science, Philadelphia, Pa., 1960. 188 pp. Paper, $2; cloth, $3.

This symposium is a noteworthy attempt to define the present place and the potential contributions of American agriculture in today's crucial situation. Charles M. Hardin has assembled a notable group of experts to deal with many facets of the problem. Highly critical, on the whole, of our current agricultural policy, the contributors do not, as so often happens, stop with critical analysis but go on to propose deep-seated reforms. It is these recommendations, clustering around a noble central theme, that give the book its special value.

The theme might perhaps be expressed in some such propositions as these:

1) In today's world "Science has given international peace the new meaning of *a condition essential for the continuance of mankind*" (from the constitution of the Society for International Development).

2) Thus international affairs have now become the foremost concern of our own and of every other nation.

3) In international affairs the prime present need is to ease intolerable stresses in an unbalanced world by enabling countries bypassed in the scientific-technological revolution to start catching up.

4) In the bypassed countries food is still the paramount need and farming still the basic pursuit; therefore agriculture is a key element in the dynamics of economic and social advance.

5) The obligation and the opportunity of the United States—and specifically of agriculture in the United States—in this process of international development is consonant in magnitude and urgency with our (hitherto) acknowledged world leadership.

6) By failing in that opportunity and obligation we risk loss of leadership to eager, confident, powerful rivals.

7) A thorough overhauling of our agricultural policy is essential if we are to succeed; and the overhauling must include the domestic as well as the international aspects, since economic weakness at home spells political weakness abroad.

This is the kind of background that inspires Hardin's frank announcement in the book's opening paragraph: "This volume is aimed at contributing to a sweeping change in the focus of American agricultural policy. . . . It hopes to influence the agenda of farm policy conferences and to command the attention of policymakers in Congress, the Executive, and farm organizations." The immediate target of this hope, it may be surmised, is whatever new administration comes to power in Washington.

It would be egregious and unjust to try to compress in a brief review the gist of 21 diverse articles (and a bibliography) contributed by 22 people and covering foreign trade; the disposal of surpluses; the export of capital, manpower, and skills; the relation of agriculture to economic growth; the overhauling of farm policy; special commodity problems; Canadian *vis-a-vis* U.S. policy; better use of human resources in agriculture; the roles of Congress and the Executive; farm organizations and farm opinion; and the Agricultural Extension Service. But some of the challenging theses that stud the volume can be indicated.

Arguing that "For the past decade American farm policies have tended to give the farmer the wrong signals" about foreign markets, Gale Johnson sketches a program of gradual but far-reaching changes and adjustments that might be carried out over a 5-year period without entailing economic distress.

Willard Cochrane outlines a seven-point, long-term plan designed to make exclusive (and extensive) use of surpluses to finance economic development.

F. F. Hill makes a case for conserving scarce scientific manpower by "concentrating United States assistance in each major region on a relatively limited number of key countries," and within each country on a limited number of key areas, institutions, and training programs. He also suggests making 5- or 10-year federal grants to colleges and universities in the United States to finance the employment of staffs for "overseas extension work."

Charles Kellogg says that huge increases in agricultural production are possible over large areas, but that in such cases there is commonly "no practical midway system between a low and a high level of inputs and outputs." "Only a drastic change is practical," and this presents highly complex and difficult problems.

In a penetrating analysis of overspecialization in our land-grant colleges and universities, Roland Renne argues for "fewer and broader curricula" with much more emphasis on "the basic principles and theories essential to develop the objective reasoning necessary for effective adaptation to varying situations and requirements in our modern society."

To prevent excessive production, G. E. Brandow would replace price control with "supply control," thus, "routing income to agriculture through the market rather than through the federal budget."

In an incisive analysis of the cotton situation, M. K. Horne, Jr., expresses the conviction that the "price-leadership" policy of the United States in the world market probably has "served as an enormous stimulus to the progress of less-developed nations," though "few kind words are ever said for it in international councils."

To alleviate the oversupply of labor in agriculture James Maddox proposes vigorous federal-state programs emphasizing nonfarm pursuits, employment assistance, and combinations of off-farm and farm work in special areas.

Lauren Soth advocates rerouting much more of our "excess agricultural resources"—including excess scientific services—to overseas development as the "least-cost" method of helping poor countries and ourselves simultaneously; but he concludes that this would require "massive changes in foreign and farm policies," which, at present, farm leaders and pressure groups would strongly oppose.

Carrying this theme a step further, Ross Talbot sees the 1960's as "the decade of decision" for which our farm policies are totally inadequate; and he proposes a White House conference on farm policy as a "new and dynamic framework" for dramatizing the problem, reconciling ideological and personality differences among the major farm organizations, and "working out a rational farm policy in terms of our national interest."

Finally, Wallace Ogg turns the spotlight on the Extension Service as an organization that must, because it is the one that can, assume responsibility for bringing about profound nationwide changes in the attitudes of college and university leaders, farmers, and nonfarm people; these changes are required to integrate foreign and domestic policy. "If the Extension Service does not accept this new role it may not be possible to have the kind of foreign agricultural policy that the world situation demands from the United States."

Symposia are *ipso facto* not uniform in quality, but as a whole this one reaches a high level of conception and execution.

GOVE HAMBIDGE
International Development Review, Kensington, Maryland

Saturday Science. Andrew Bluemle, Ed. Dutton, New York, 1960. 333 pp. Illus. $5.95.

Accelerators. Machines of modern physics. Robert R. Wilson and Raphael Littauer. Doubleday, New York, 1960 (available to secondary-school students and teachers through Wesleyan University Press, Columbus 16, Ohio). 187 pp. Illus. Paper, $0.95.

The current ferment in public education is illustrated by the publication of these books. They represent two of the many recent programs aimed at improving high-school science education. In addition, their availability to the general public illustrates the way in which many of these programs are growing in scope, influencing other levels of formal and informal education.

Saturday Science is a compilation of articles by scientists from the Westinghouse Research Laboratories. In recent years, Westinghouse has invited many outstanding high-school seniors to attend a series of Saturday morning lectures by staff scientists who discuss their own research fields. The students are considered to be members of the Westinghouse Science Honors Institute.

A group of the Saturday morning lectures have been rewritten for this book. Although the origin sometimes shows, for on many occasions the reader misses the exciting demonstrations which must have illustrated the sessions, the translation into printed form succeeds well.

The book is divided into two parts. The first (9 chapters), called "Some principles," has subjects ranging from radioactivity to the chemistry of solids to propulsion. The second part, entitled "Some techniques," considers mathematical and experimental methods for scientific study.

The book jacket announces that a new series of educational television programs, "Lab. 30," is being based in part on *Saturday Science*. The television series should benefit from the scientific competence of the contributors to the book.

By now, most scientists have heard of the exciting, controversial work of the Physical Science Study Committee. Their reworking of the high-school physics course has encompassed a new textbook, laboratory materials, films, and a series of monographs on special topics in physics. Their ideas are filtering upwards and downwards in our educational system, influencing course-content and presentation in colleges and universities and in the lower grades of public schools.

Characteristically, the monographs in the "Science Study Series" are intended for the general public as well as for students. Almost 100 volumes are planned, all on topics within or relevant to physics, and all written by experts. [For reviews of published volumes see *Science* **130**, 616 (1959) and **131**, 219 (1960)]. *Accelerators* is a fine example of the excellence of the series. Wilson is the director of the Laboratory of Nuclear Studies at Cornell University, and Littauer is one of his colleagues. Both have had extensive experience in the design of accelerators and in their use in significant experiments.

The book begins with a discussion of why physicists need high-energy accelerators, and it proceeds to give a historical account of their development, always clarifying the physical principles employed. It discusses the Cockroft-Walton machine, the Van de Graaff accelerator, the other linear accelerators, and the many circular machines. The limitations of the various accelerators are indicated along with the techniques which overcome some of the limitations. The book concludes with a discussion of acceleration on a grander scale—that which produces cosmic rays.

Accelerators is well-written and should prove understandable to anyone with a command of only elementary physics. By having the reader concentrate in detail on a single topic, the book should present him with additional perspective on the broad range of physical principles relevant to a penetrating study in a special field.

HOWARD LASTER
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Pasteur and Modern Science. René Dubos. Doubleday, New York, 1960 (available to secondary-school students and teachers through Wesleyan University Press, Columbus 16, Ohio). 189 pp. Illus. $0.95.

This book is a tribute to the man as well as a critical study of the life and accomplishments of one of the most celebrated and dedicated scientists of all time, Louis Pasteur. The author has met with a large measure of success in his endeavor to explain the influence of Pasteur's contributions upon the development of scientific progress in his own time and its continuing influence upon modern research.

René Dubos discusses how Pasteur moved forward in a logical sequence from his studies of crystals to his research on fermentation. The unchallenged evidence of his experiments overthrew the theory of spontaneous generation—a triumph that gave rise to modern microbiology and bacteriology. The author then elaborates on pasteurization, and he follows this with a detailed, fresh approach to Pasteur's theories on contagious diseases. These theories helped to expand researches in this field to include what Dubos beautifully and accurately calls "the domestication of microbial life." Dubos emphasizes Pasteur's awareness of the possibilities of controlling and destroying infective microorganisms not only by acting directly on them in their modified environment in the host body

but also by the aid of other microbes, a precursory approach to treatment by antibiotics. Enthusiastically the author points to immunology, which Pasteur considered a natural law, and to Pasteur's dream of "chemical vaccines" which actually led to the birth of immunochemistry.

In his masterly translation of quotations, mainly from French sources, Dubos presents their meaning in harmony with the text. It is regrettable, however, that he neglects to document such information properly or to give a general bibliography. He might also have eliminated the unnecessary, repeated interruption of his narrative, had he given the whole biography of Pasteur in the opening chapter instead of scattering it throughout the text (see pages 34, 38-43, 63, 128-9, and 176-8). In this manner, the reader could have been acquainted with Pasteur the man, as an introduction to Pasteur the scientist.

Although the author does not explicitly mention that this volume was intended as a contribution to the history of science, its presentation of the development of biological sciences deserves great praise for filling a gap in the history of science.

SAMI HAMARNEH
Division of Medical Sciences, Smithsonian Institution

Thoracic Surgery Before the 20th Century. Lew A. Hochberg. Vantage Press, New York, 1960. 858 pp. Illus. $15.

Thoracic surgery came of age during the three decades encompassed by the First and Second World Wars, and it has undergone a phenomenal expansion in recent years. It is appropriate that a comprehensive history of thoracic surgery should be brought forward at this time. Such a survey, aside from its humanistic values, may serve as a guide for the future efforts of those laboring in this subdiscipline and as insurance against repetition of some past errors. Lew Hochberg has accepted this challenge at an opportune time, but as the title of his book suggests, in an incomplete fashion. Perhaps because of the enlarging scope of thoracic surgery, the rapidity of present changes, and a reluctance to sit in judgment on his contemporaries, the author has deliberately restricted himself, carrying this subject only through the closing years of the last century.

There are not many phases of thoracic surgery the evolution of which can be considered complete, or nearly complete, by 1900. The specialist in thoracic surgery, of course, can supply his own concluding chapters, but the lay reader or the occasional student of medical history may feel that he has been left dangling and that the final acts of a fascinating drama are still to be played out.

Hochberg treats the events of the medieval and Renaissance periods comprehensively in several well-written chapters. Beginning with the 1800's, however, he elects to approach the burgeoning material by individual subjects; for example, empyema, pulmonary suppuration, tuberculosis, diaphragmatic hernia, the mediastinum, the esophagus, and the heart and great vessels. Certain of these sections are more descriptive than interpretive. The writer uses freely the technique of lengthy direct quotations (with translation as necessary) from the original sources to lend, as he states, "authenticity to the present work and help correct some of the misquotations noted in the literature." His technique has accomplished these objectives, while yielding some insight into the hearts and minds of earlier surgeons as they sought new light to guide them on unfamiliar paths, and as they courageously made the trials that left them wide open to the criticisms and even abuse of their less enterprising and imaginative colleagues. But in so doing, Hochberg has been unavoidably repetitious, especially in the more than 80-page section on empyema. Whenever possible, however, he lightens this heavy fare with lively biographical sketches and entertaining vignettes of key personages.

Appended to the main text is a series of chapters, entitled "Nonsurgical contributions to the advancement of thoracic surgery." Those sections concerning percussion, auscultation, vital capacity (perhaps better titled "Estimation of pulmonary function"), and peroral endoscopy are excellent reading, among the best in the book. But in other chapters, antisepsis, anesthesia, and x-rays receive more cursory treatment, and of course these topics have implications beyond the scope of this work.

During the 20 or more years that the author has been delving into medical history he has turned up a great volume of important, and some new, material which will make his *Thoracic Surgery Before the 20th Century* a valuable source book for the serious student, as well as an easy reference work for the educator who illuminates his lectures and writings with appropriate historical notes. Time and again the reader is made aware that the first solution proposed for many surgical problems was an inspired and theoretically correct one, but finally rejected or forced to yield to necessary compromise or improvisation because of inadequacies in surgical technique, anesthesia, and supportive therapy. Those adjuncts are taken for granted in the present day and ensure almost routine success for modern surgeons, who may be less thoughtful and even less skillful than their sometimes frustrated predecessors.

Many of the 155 illustrations in this book are rare finds, and they deserve better reproduction than Vantage Press has managed to provide.

Hochberg's style of writing is simple, precise, and clear, attesting to the truth that the pursuit of medicine is still compatible with proficiency in the field of letters. The publication of his projected companion volume on the thoracic surgery of the present century will be eagerly awaited.

GUSTAF E. LINDSKOG
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Nuclear Photo-Disintegration. J. S. Levinger. Oxford University Press, New York, 1960. 144 pp. $2.

In this monograph J. S. Levinger summarizes all the available theoretical ideas about the nuclear photoeffect and relates them to the experimental results. Two outstanding chapters reflect the author's interest in sum rules and models. He begins by considering the fundamental interactions between photons and charges; the concept of oscillator strength is introduced, and sum rules are discussed and used to calculate the different moments of the charge distribution. These ideas are initially set forth for an atomic system, and then the proper modifications are made so that they become applicable to a nuclear system. Levinger emphasizes that the main features of the nuclear

photoeffect may be obtained from sum-rule calculations and are independent of the model assumed for the nuclear ground state. The nuclear systematics derived from sum rules are compared with experimental results, and reasonable agreement is demonstrated.

In the chapter devoted to models Levinger points out that both of the apparently conflicting models — the shell model and the collective model—are incomplete and that the truth surely includes them both. The relationships between the models are discussed, and distinctions are made between those features of the photon absorption cross section that are model-dependent, and therefore can be used to decide between models, and those that are model-independent.

The remaining chapters are devoted to deuteron photodisintegration, electromagnetic transitions between discrete energy levels, and the products of nuclear photodisintegration; they summarize experimental results and relate them to existing theories.

This little book is clearly a must for the specialist in photonuclear reactions. Those working in other branches of nuclear physics will find it a helpful summary, and the atomic physicist will enjoy seeing the connection between the atomic and nuclear problems.

EVANS HAYWARD
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Food, the Yearbook of Agriculture, 1959. U.S. Department of Agriculture, Washington, D.C., 1960 (order from Supt. of Documents, GPO, Washington 25). xii + 736 pp. Illus. $2.25.

Food is important in keeping our people and our country strong. An abundance of food and the means of purchasing it are blessings of our economy. But do we know how to obtain the maximum vigor and vitality from the food we use? This question cannot be answered in the same affirmative sense. Despite spectacular progress made in biochemistry and nutrition during the last 30 years (about 50 essential nutrients have been discovered), the chapter on unidentified substances (by George M. Briggs) shows that we do not yet know all of the nutrients and that many new discoveries—such as the discovery that compounds containing selenium have important nutritional properties—are to be expected. On the other hand, the vast amount of knowledge already collected in the nutritional field has not yet reached the consumer; this could help the consumer in selecting his food and in preparing it in such a way that he could obtain the best possible nutritional benefits without sacrificing any of the pleasures of a well-prepared meal.

Because of the complexity of the subject matter, the outstanding textbooks of nutrition require a background in chemistry and physiology which even educated laymen do not possess, while most of the volumes written as popular books do not offer the information necessary for rational food planning and, in many instances, they even offer misinformation. This broad gap between two much and too little science is filled in an admirable way by the recently published *Yearbook of Agriculture, 1959*; its 65 chapters, written by eminent experts in all fields of nutrition, constitute a comprehensive presentation of our present knowledge of food and nutrition. While most of the well-written chapters are of a practical nature—for example, Elsie H. Dawson explains what happens to food in cooking—some chapters will appeal to scientists and will provide balanced information to those who have not specialized in the particular field of research covered in the chapter. I will mention only the chapter on metabolism (by Raymond W. Swift), the chapters on proteins and amino acids (by Ruth M. Leverton), and the one on fats and fatty acids (by Callie Mae Coons). The chapter on fat-soluble vitamins, written by the old master of nutrition, E. V. McCollum, shows that either too little or too much of a vitamin—for instance, vitamin C—may have harmful effects; the chapter on vitamin B complex (by Grace A. Goldsmith) records many interesting details about vitamin B_{12} and other less known vitamins of the group which, in minimal amounts, may exert a profound influence on our well being. Thus, the book will offer scientists and laymen alike a storehouse of theoretical and practical knowledge.

Hazel K. Stiebeling, of the Institue of Home Economics, organized the work and wrote an interesting chapter on the impact of food on human life.

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New Books

General

American Assembly, Columbia University. *The Federal Government and Higher Education.* Prentice-Hall, Englewood Cliffs, N.J., 1960. 205 pp. $3.50. Final report of the 17th American Assembly.

Battista, O. A. *Commonscience in Everyday Life.* Bruce, Milwaukee, Wis., 1960. 122 pp. $2.75.

Corte, Nicolas. *Pierre Teilhard de Chardin.* His life and spirit. Translated by Martin Jarrett-Kerr. Macmillan, New York, 1960. 140 pp. $3.25.

Edfeldt, Åke W. *Silent Speech and Silent Reading.* Univ. of Chicago Press, Chicago, Ill., 1960. 172 pp. $3.50. In the first part of this book, Edfeldt discusses the search for a proper method for investigating the true nature of silent speech, reviews earlier work, and describes the electromyograph (the instrument used in his experiment). Part 2 is a report of an actual experiment and a discussion of prevalent theories of silent speech.

Iverson, Robert W. *The Communist and the Schools.* Harcourt, Brace, New York, 1959. 435 pp. $7.50. The second volume in a series of studies of Communist influence in American life. The editor for the series was Clinton Rossiter; the survey was supported by the Fund for the Republic.

Kindler, Herbert S. *Organizing the Technical Conference.* Reinhold, New York; Chapman and Hall, London, 1960. 150 pp. $6.

Morris, Richard T. *The Two-Way Mirror.* National status in foreign students' adjustment. Univ. of Minnesota Press, Minneapolis, 1960. 229 pp. $4.50. The subjects of this study were 318 students from some 65 countries who were enrolled at the University of California at Los Angeles. The study seeks to determine to what extent the image of their native countries which the students believed Americans held influenced the foreign students in their reactions to their American experiences. It is the fifth study in a series of monographs resulting from a program of research sponsored by the Committee on Cross-Cultural Education of the Social Science Council.

Reinfeld, Fred. *What's New in Science.* Sterling Publishing Co., New York, 1960. 204 pp. $3.95.

Rubin, Theodore Isaac. *Jordi.* Macmillan, New York, 1960. 73 pp. $2.95.

Salzman, Michael H. *New Water for a Thirsty World.* Science Foundation Press, Los Angeles 3, Calif., 1960. 227 pp. $5.95.

Steen, Edwin B. *Dictionary of Abbreviations in Medicine and the Related Sciences.* Davis, Philadelphia, Pa., 1960. 102 pp. $2.50. Examples of contents: "HE viruses: human enteric viruses"; "RE: Radium emanation, reticuloendothelium, right eye."

Steiner, Rudolf. *Friedrich Nietzsche.* Fighter for freedom. Translated from the German by Margaret Ingram deRis. Rudolf Steiner Publications, Englewood, N.J., 1960. 222 pp. $4.75. Volume 2 of the major writings of Steiner, published in commemoration of the hundredth anniversary of his birth (1861).

Reports

Perception of Apparent Motion in the Common Toad

Abstract. A simple and inexpensive apparatus makes possible the feeding of nonliving objects to the toad. The device is used to demonstrate the perception of apparent or "induced" motion. Two methods are successful: (i) toad and food moving together at a constant velocity in a stationary environment; (ii) toad and food stationary with the environment moving. The phenomena are similar to those found in human beings.

Although the common toad is a fascinating specimen for the home terrarium and an interesting subject for the laboratory, its refusal to eat nonmoving food presents something of a problem in maintenance, particularly during the winter. Keeping colonies of earthworms, meal worms, or crickets is troublesome; hand-feeding by waving a pellet of hamburger on a toothpick in front of each individual is tedious. The apparatus described below makes it possible to feed a toad any food that it finds palatable. Hamburger is satisfactory (we maintained several toads for over a year on it), but toads will eat foods other than meat, including laboratory chow, carrots, and some breakfast cereals.

A 1/5 rev/min motor (Haydon Manufacturing Co., No. 8478, 2 watt) was mounted in the center of a strip of wood long enough to straddle the terrarium. A vertical shaft was attached to the center of a 12.9-cm metal disk (we used a lid from a 1-lb can of pipe tobacco). The disk was flush with the ground level of the terrarium. Small pellets of hamburger were placed on the rim of the slowly revolving disk. The toads *(Bufo terrestris)* approached the rim, flicked their tongues, and consumed the food. Five or six toads, each oriented toward the center of the disk, knocking off pellets of hamburger (accuracy, 95 percent) like sharpshooters potting ducks in a shooting gallery, make a spectacular sight. The apparatus might make an interesting demonstration for zoos, children's museums, or a science fair.

Our observation of the toads feeding from the motorized Lazy Susan led to the study of perception of apparent or "induced" movement. Toads frequently crawled onto the turntable itself. They faced the food on the rim, flicked their tongues, and swallowed the food. One hundred observations on 20 toads 2 to 8 cm long revealed 85 successes—that is, tongue flicks followed by consumption of food.

Since toads eat only moving objects, and the toad and food were stationary on the turntable, one concludes that the movement of the background induced the perception of motion. This interpretation is similar to a principle recently stated by Wallach (*1*), which seems to hold for perception of motion in human beings: ". . . visual perception (of motion) follows the rule that keeps the surrounding at rest and bestows motion upon the object surrounded." An example of this characteristic of perception occurs in the railway station when the train on the adjacent track pulls out. One has the sensation that one's own train is moving. Another example is the apparent motion of the moon when seen among drifting clouds.

Even though Honigmann (*2*) in his survey of the literature concludes that there is no convincing evidence that olfactory and visual cues are sufficient to elicit the flicking response in amphibians, a control experiment was performed because of the key importance of this assumption in the chain of reasoning attributing the results of the first experiment to apparent motion. The subjects were placed on a 1-, 2-, and 3-day food-deprivation schedule. The half-hour observation was divided into 5-minute periods. The motor was turned on during alternate periods. No toad tried for the food when the platform was stationary, although several stared at a pellet for a full 5 minutes. When the turntable moved, the toads immediately began to feed.

A consequence of the principle of induced motion is that toads should eat in a situation in which the food and the toad are stationary and the environment moves. This was the case. A cylinder 13 cm in diameter and 21 cm high, constructed of 2-mm mesh window screen and closed at one end (two inner hoops and one lid from tobacco tins were used in its construction) was attached to the motor shaft, the open end down. A band of plain white paper 10 cm wide was placed around the outside of the cylinder. The toad and the food were placed on a white stationary base within the cylinder. Food pellets were placed so as to just clear the inside of the moving cylinder. Feeding was not immediate; there was an interval of from 5 seconds to several minutes before the toads began to eat. Fifteen toads made a total of 100 tries; 80 were successes. One subject failed to respond on the day of the experiment but responded the next day.

Honigmann (*2*), after a most ingenious series of experiments on the toad's perception of "real" motion and several failures to demonstrate perception of "induced" movement, doubted the existence of the latter in lower vertebrates although, on the basis of another study (*3*), he believes that it may occur in birds. Honigmann's apparatus permitted vertical movement of the background, horizontal movement of the background, movement of the food, and movement of the toad, either individually or in combinations. However, the background moved was only that directly in front of the toad. The failure to demonstrate perception of induced movement may have been due to the nature of the visual field of the toad, which, because of the position of the eyes, has a shape roughly resembling an inverted cantaloupe half (360° ×180°). Moving the background in front of a toad changes only a fraction of the visual field. In our experiments a large portion of the visual field was moved.

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References

1. H. Wallach, *Sci. American* **201**, 60 (1959).
2. H. Honigmann, *Proc. Roy. Soc. London* **B132**, 306 (1944).
3. ——, *J. Exptl. Biol.* **19**, 156 (1942).

28 June 1960

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

Developmental Selection of Mutations

Abstract. The direction of evolution may at times be determined by the internal selection of genotypes during development, rather than by the external selection of phenotypes. Biological theory and experiment have reached the point where those concerned with evolutionary problems or with nuclear and cellular organization should consider this possibility.

In studies of the genetic basis of the theory of evolution by natural selection there has been, until recently, little explicit consideration of the possibility that the internal developmental selection of mutations (in contrast to the environmental selection of developed organisms) may sometimes be an important factor in determining the direction of evolutionary change. Some degree of developmental selection of genotypes has occasionally been considered to be probable, and is indeed implicit in the conception of lethal mutations. But the fact that the internal developmental selection of genotypes, rather than the external adaptive selection of phenotypes, may at times be the primary factor determining the direction of evolutionary change has seldom been made explicit (*1*). Though environmental selection is always selection of the ultimate developmental effects of genes, the internal selection of genes and of their earlier effects is a distinct process which merits more consideration than it has yet been given. A line may be drawn between the two at the moment when the developing zygote faces a nonparental environment.

In any structural view of organisms point mutations unrelated to the structure of the organism, or other accidental structural rearrangements, which occur in a highly patterned chromosomal and other neighborhood, will necessarily be subject to a complex and progressive selective process in which the criterion is compatibility with the internal structure and processes of the system, in particular with chromosomal activities. It is widely agreed that in certain respects the genes act as unblending units, and in others as cooperative or "coadaptive" elements in an ordered gene complex which must satisfy certain over-all conditions if an adequately coordinated organism is to result, but little is known regarding these conditions.

The internal selective process may be roughly divided into two phases: (i) some mutations will not adequately conform, at their locus, to the specific ordered molecular structure characterizing the genic system and may therefore be physically or biochemically unstable and be at once eliminated; and (ii) some of those surviving this test will prove less capable (or incapable) of having their activity coordinated within the highly ordered processes of replication, activation, differentiative development, and prefunctional activity, and either they will be modified (by a return mutation or otherwise) in the course of these processes so that they do adequately conform, or, the resulting structures will damage the internal coordination and in severe cases arrest development. Mutations at any locus, to be nonlethal, must possess specific features which, though not yet understood, may play a part in determining the evolutionary process at certain times possibly equal to that of environmental adaptation. "Natural" selection, understood in the full sense, comprises two separable selective processes: developmental selection (where the criterion is internal organizational efficiency permitting continued growth), and environmental selection (dependent on adaptive success, permitting continued life and reproduction). Any phenotype which is adaptively successful must correspond to a genotype which has passed the internal selective process, but that is no reason for neglecting to consider the effects of internal selection, as far as knowledge permits. In much current writing on genetic and evolutionary theory terms such as "natural selection," "adaptive," "favorable," and so forth, are used in a manner which excludes internal developmental selection.

In the view presented here initially haphazard mutations are rapidly sifted, the particular organism choosing what is sufficiently compatible with its existing specific structure. The struggle for survival of mutations begins at the moment mutation occurs. Members of a viable species must be not only adaptively well adjusted, but internally well coordinated, and the latter property is tested first and may, in certain respects or during certain periods, be the more severe restriction on permissible mutations.

The effect of this internal organizational selection of mutations on evolutionary change has received relatively little analysis, probably because until recently it lay outside the scope of biological experiment (*2*) and theory (*3*). But if a prior selective process operates on the mutated genotype, in terms of its compatibility with the highly specific structural processes of development—and it is hard to see how this could fail to be the case on any structural theory of organisms accounting for their coordination—then many arguments concerning evolution by natural selection (gene stability, rates of variation, speciation, macroevolution, and so forth) may have to be reconsidered. The absence of direct evidence for such an effect does not justify its neglect by evolutionary theory, if it is a natural inference from any structural interpretation of organic processes.

The purpose of this note is to invite the attention of specialists to three questions: (i) What evidence exists for developmental selection and what light does the evidence throw on the criteria involved? (ii) What contribution can chemical or other theories of cellular or nuclear organization make to this issue? (iii) Under what circumstances may developmental selection play a decisive role in determining the direction of evolution?

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References and Notes

1. Some relevant references are: H. T. Pledge, *Science Since 1500* (Harper, New York, 1959), p. 226 ("the gene-complex is an 'environment' for mutations in the organism"); I. I. Schmalhausen, *Factors in Evolution* (Blakiston, New York, 1949) (The idea of developmental selection appears to be used, though not made fully explicit); C. H. Waddington, *Strategy of the Genes* (Macmillan, New York, 1957), pp. 65–66 (The possibility of selection acting directly on the mutated genes is considered but dismissed); T. Dobzhansky, *Genetics and the Origin of Species* (Columbia Univ. Press, New York, 1937) (Evolutionary paths may conceivably diverge owing to genetic control of the *directions*, as well as the *rates*, of mutation); J. B. S. Haldane, in *Darwin's Biological Work*, P. R. Bell, Ed. (Cambridge Univ. Press, Cambridge, 1959), p. 147 (Haldane says that if certain mutations "interrupt some important developmental process . . . the possibilities of evolution open to a species depend not so much on its genes and their mutability, as on its developmental processes"); ———, *J. Genet.* **56**, 11 (1958); J. H. Woodger, in *The Axiomatic Method*, L. Henkin *et al.*, Eds. (Humanities, New York, 1959), p. 427 (Woodger stresses the importance of random development, as well as random union of the gametes, in obtaining the Mendelian ratios).
2. One of the first observational indications of the internal selection of mutations was reported by Lima-de-Faria [*Chromosoma* **5**, 1 (1952); see p. 53]. See also C. H. Waddington, *Strategy of the Genes*, p. 66, on mutator genes.
3. The possibility of coordinated chromosomal action, which is connected with the present argument, has been discussed by Schmalhausen in *Factors in Evolution*, by R. B. Goldschmidt in *Theoretical Genetics* (Univ. of Calif. Press, Berkeley, 1955), p. 184–186, and 487, and by Waddington in *Strategy of the Genes*. But conceptions such as "autoregulation," "canalization of development," "systemic mutations," and so forth, might be better defined by explicit consideration of developmental selection.

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8 April 1960

Atropine-like Actions of Muscarine Isomers

Abstract. Molecular pharmacology of muscarine isomers has been studied in the rat intestine and frog heart. The significance of the peculiar finding of atropine-like action of some of the isomers is discussed.

The activity of a drug is mainly characterized by affinity and intrinsic activity (*1*). The intrinsic activity, representing the ability of a drug to produce an effect, is also a measure of the

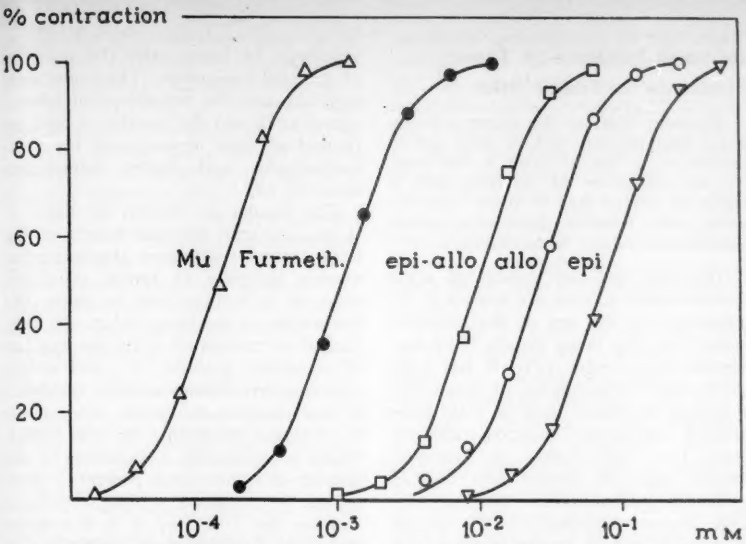

Fig. 1. Cumulative dose-response curves on the rat intestine for furtrethonium and the muscarine isomers. Note a difference in the affinity as a difference in the place on the contraction axis and an identical intrinsic activity as an equal maximal height.

ratio between agonistic and competitive antagonistic actions.

Postganglionic parasympathetic stimulants, parasympathomimetics, or muscarinics have a high intrinsic activity, whereas postganglionic depressants, parasympatholytics, or atropine-like drugs have a very low intrinsic activity. Minor changes in the molecular structure of parasympathomimetic drugs result in considerable changes in both the affinity and the intrinsic activity (*2*). For instance, substitution of a propyl group for the methyl group in the hydrofuran ring of muscarine causes a change from parasympathomimetic to parasympatholytic action. DL-Propyl-demethylmuscarine (*3*) thus is a purely competitive antagonist of a parasympathomimetic such as furtrethonium (*4*).

It has been clearly demonstrated that optical isomers of parasympathetic drugs differ largely in their affinity for the receptors (*5*). It is to be expected also that differences in the intrinsic activity will be found for stereoisomers, even to the extent that for certain parasympathetic drugs isomers will be found which exert atropine-like actions. In this respect it seemed worth while to investigate the stereoisomers (*6*) of DL-muscarine, which have been found to differ in potency (*7*).

DL-Muscarine appeared to be the most potent parasympathomimetic of the four possible racemates (*8*).

From the cumulative dose-response curves (Fig. 1) it may be seen that these isomers all behave as pure parasympathomimetics on the rat intestine. They have equal intrinsic activities (Table 1). Consequently, the difference in potency must be attributed to differences in their binding capacity with respect to the receptor.

The intrinsic activity, however, depends not only on the molecular structure of the drug but also on the molecular structure of the receptor. Consequently, the intrinsic activity of parasympathetic drugs may vary for different species and organs. It is known that the activity is generally found to be lower in the frog heart than in the intestine (*9*). For instance, the action of pilocarpine is largely parasympathomimetic on the intestine but almost purely atropine-like on the frog heart (*10*).

Indeed, it could be established that not all four isomers act upon the frog heart as pure parasympathomimetics, but that atropine-like actions become apparent in DL-epimuscarine and DL-allomuscarine. DL-Epimuscarine is able to antagonize the action of acetylcholine on the heart (Fig. 2, left). These atropine-like actions of epimuscarine can be overcome by increasing the concentration of acetylcholine, while epimuscarine also protects the heart against high doses of acetylcholine (Fig. 2, left). These experiments suggest a competitive inhibition of the effects of acetylcholine by DL-epimuscarine, indicating that the latter is a true parasympatholytic drug. The intrinsic activity consequently is very low (Table 1). DL-Allomuscarine is

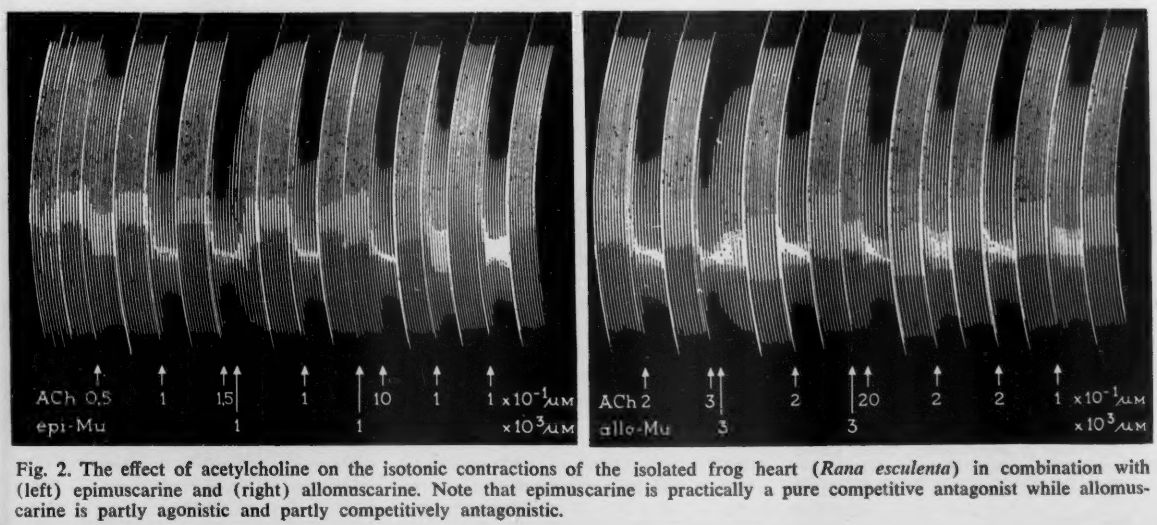

Fig. 2. The effect of acetylcholine on the isotonic contractions of the isolated frog heart (*Rana esculenta*) in combination with (left) epimuscarine and (right) allomuscarine. Note that epimuscarine is practically a pure competitive antagonist while allomuscarine is partly agonistic and partly competitively antagonistic.

Table 1. Intrinsic activities (α) and affinities (pD_2 or pA_2 values). Ach, acetylcholine; DL-allo-mu, DL-allomuscarine; DL-e/al-mu, DL-epiallomuscarine; DL-epi-mu, DL-epimuscarine; DL-mu, DL-muscarine; DL-pr-mu, DL-propyldemethylmuscarine; H fur, furtrethonium.

Substance	Rat jejunum			Frog heart		
	α	pD_2	pA_2	α	pD_2	pA_2
Ach	1	7.1		1	7.2	
H fur	1	5.9		1	5.9	
DL-mu	1	6.8		1	6.4	
DL-e/al-mu	1	5.0		1	4.5	
DL-allo-mu	1	4.4		0.4		3.7
DL-epi-mu	1	3.9		0.1		3.8
DL-pr-mu	0		4.7			5.1

partly parasympathomimetic and partly parasympatholytic (see Fig. 2, right). High doses of acetylcholine are antagonized by allomuscarine only to a certain degree, whereas allomuscarine, as such, depresses the heart beat to the same degree. Hence DL-allomuscarine is a parasympathetic drug with a dual action, or a partial agonist. Both DL-muscarine and DL-epiallomuscarine have purely parasympathomimetic action on the frog heart. The affinities, expressed as pD_2 or pA_2 values (*11*), and the intrinsic activities of the whole series are shown in Table 1.

The results establish that the affinity and intrinsic activity depend not only on the molecular structure of the drug but also on that of the receptor (*12*).

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7 June 1960

Increased Incidence of Tumor Metastases in Female Mice

Abstract. Most of the tumor cells injected into the tail vein of mice fail to survive at the site of arrest in the lungs, but the percentage of surviving cells is higher in females than in males. The surviving cells, however, grow at a similar and constant rate in both sexes.

The take and the growth of some transplantable tumors are known to be influenced by the sex of the recipient animal, females being usually more susceptible than males (*1*). It has been shown that the incidence of metastases is higher in female than in male mice bearing chemically induced skin tumors (*2*), and higher in estrogen-treated than in control rats bearing spontaneous mammary tumors (*3*). This higher susceptibility of female animals to tumor transplantation and metastasis may be explained through one of two mechanisms: either an increased growth rate of the tumor or an increased survival of the tumor cells originally injected or disseminated through the metastatic pathways.

In previous studies, using tritiated thymidine to label the dividing cells, we investigated the fate and the growth rate of Ehrlich ascites tumor cells injected intravenously into strain CAF_1 female mice (*4*). It was found that 99 percent of the tumor cells lodging in the lungs died in the first 48 hours, and that, from the 3rd day on, the surviving tumor cells grew at a constant rate. About 40 percent of the cells were labeled by a single injection of tritiated thymidine.

In connection with this experiment, a number of male CAF_1 mice, together with the females, were given 6×10^6 Ehrlich ascites tumor cells, from male donors, by injection into the tail vein. The animals were then randomized into four groups, each group receiving a single intraperitoneal injection of tritiated thymidine (30.5 μc per animal) at 1, 48, or 240 hours after the injection of tumor cells. The animals were sacrificed 24 hours after the injection of tritiated thymidine. The lungs were weighed, and the percentage of labeled tumor cells and the uptake of tritiated thymidine were investigated by autoradiography and liquid scintillation counting (*4*).

The results are shown in Table 1. It may be seen that the weight of the lungs increases with time after the intravenous injection of tumor cells, but more so in females than in males. As the weight of the lungs in animals thus treated is correlated with the number of secondary growths (*5*), this weight discrepancy indicates a lower incidence of metastases in the males. The uptake of tritiated thymidine by the lungs, which is essentially a function of the amount of tumor tissue present in these organs (*4*), follows a similar pattern, and on the 10th day it is five times higher in females than in males. It may also be seen that, if the tritiated thymidine label is taken as a criterion of viability of a tumor cell, the great majority of the injected tumor cells fail to survive at the site of arrest in the lungs; the number of surviving cells, however, is 10 times larger in the females than in the males. After 48 hours the percentage of labeled tumor cells, which is then a function of the growth rate of the tumor, is the same in both males and females. On the 10th day after tumor injection, the percentage of labeled tumor cells is again the same in both sexes. It should be added that, in the females, the growth rate of this tumor is known to be constant from the 3rd to the 12th day after the intravenous injection (*4*).

These data indicate that, under the conditions of the experiment reported here, the increased number of metastases in female mice, as evidenced by the heavier weight of the lungs and the higher uptake of tritiated thymidine, is due to an increased survival of injected tumor cells lodging in the lungs. Once established in the lungs, the tumor cells grow at a similar and constant rate in both sexes. It is sug-

Table 1. Uptake of tritiated thymidine in the lungs of mice injected intravenously with tumor cells. All animals were injected intravenously with 6×10^6 Ehrlich ascites tumor cells and, at the indicated intervals thereafter, with 30.5 μc of tritiated thymidine intraperitoneally.

Animals		Interval between injection of tumor cells and tritiated thymidine	Mean wt. of lungs (mg)	Uptake ($\mu c \times 10^2$)	Labeled tumor cells (%)
No.	Sex				
3	M	1 hr	226	1.55	>0.1
3	F	1 hr	232	1.38	0.8
3	M	24 hr	234	1.95	>0.1
3	F	24 hr	219	2.97	10.0
3	M	48 hr	216	5.40	35.0
3	F	48 hr	275	5.73	35.0
3	M	10 day	311	6.98	40.0
3	F	10 day	591	38.15	38.0

gested that this technique may be of some value in separating the two processes—percentage of cells surviving at the site of arrest or injection and growth rate of the surviving cells—in the investigation of the various factors (*6*) known to influence the incidence of tumor metastases (*7*).

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5 July 1960

Couplet Periodic Breathing Response to High Carbon Dioxide and High and Low Oxygen

Abstract. A breathing pattern is described which is characterized by a grouping of two breaths followed by a prolonged apnea and which may involve a mechanism different from at least one type of Cheyne-Stokes breathing. The pattern can be eliminated by breathing 9 percent O_2 or 10 percent CO_2. However, the pattern frequently persists during breathing of high oxygen.

Considerable time and effort have been devoted to the study of periodic breathing since the early observations of Cheyne (*1*) and later of Stokes (*2*). The respiratory pattern named after these men is characterized by a series of breathing efforts gradually increasing in magnitude to a peak followed by a gradual decrease, each series of respiratory efforts being separated by an apneic period sometimes lasting for 60 seconds or longer. Later, Biot (*3*) published a monograph on Cheyne-Stokes breathing in which he discussed another type of respiratory irregularity, sometimes seen in meningitis, calling attention to its differences from Cheyne-Stokes breathing. Conner (*4*) has made additional observations on this breathing pattern and re-emphasized the fact that Biot's breathing is marked by complete irregularity of amplitude and duration of the apneic periods. Thus Biot's breathing is visualized as an arrhythmic variation of respiration while Cheyne-Stokes breathing is considered to be a rhythmic variation. Precision in the classification of these two types of breathing has not always been evident, for there has been some tendency to identify any deviation from "normal" as Cheyne-Stokes breathing. Recently this looseness in terminology has again been called to account (*5*).

This report concerns the possibility of the existence of another type of respiratory irregularity distinct from those previously described (*6*).

Dogs anesthetized with thiopental sodium-chloralose sometimes show a regularly grouped pattern of breathing which is characterized by two (occasionally three or more) breaths separated in time by 3 to 5 seconds, followed by a more prolonged apneic period. Frequently this breathing pattern can be induced by giving additional injections of thiopental (Fig. 1). This couplet pattern is similar to Cheyne-Stokes breathing in that it is a rhythmic variation. However, its form differs from Cheyne-Stokes breathing in several respects: there are fewer breaths per group, the apneic phases are of shorter duration, the breaths are of about the same amplitude, and the breaths are apparently not as labored as are those at the peak of the breathing phase in Cheyne-Stokes respiration. The couplet pattern is not similar to Biot's breathing, which is an arrhythmic variation. In a strict sense Biot's breathing is not truly periodic but merely respiratory events appearing in a disoriented fashion.

The couplet pattern is always eliminated by breathing 9 percent oxygen. The significant stimulation of breathing occurring with this gas mixture indicates that the chemoreceptor mechanisms are functional.

In response to breathing 10 percent CO_2 (21 percent O_2) there usually appears a stimulation which eliminates the couplet pattern. Thus it is not essential that the animal be nonresponsive to CO_2 before the respiratory variation is evident, although some depression of the respiratory center is inevitable after the administration of thiopental. On occasion, however, the couplet pattern may appear spontaneously without administration of additional thiopental. In a few cases the administration of CO_2 caused a progressive increase in the number of breaths per group and a decrease in the duration of the apneic periods. In this latter situation there is presumably a more pronounced depression of the respiratory center.

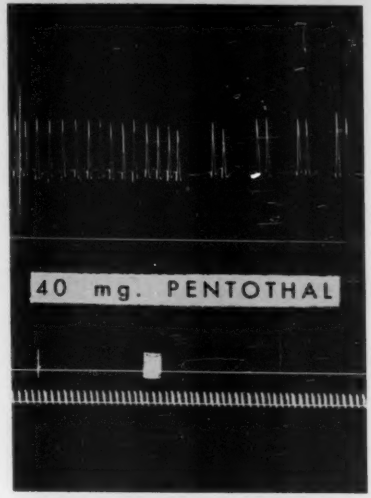

Fig. 1. Production of couplet periodic breathing by the intravenous injection of thiopental (Pentothal). The tracings (top to bottom) are as follows: pneumographic respiration, signal, and time (each tick represents 2 seconds).

In about half the cases the couplet pattern persisted during breathing of 50 to 100 percent O_2 although the apneic periods were prolonged without significant alteration of the time between the grouped breaths (Fig. 2). The various reports that high O_2 is effective in eliminating one type of Cheyne-Stokes breathing suggest that the grouped breathing here described may involve a different mechanism.

It also appears that these two respiratory patterns are not merely different stages in a progressive disruption of respiration, but rather distinct entities involving at least some differences in method of operation. This hypothesis

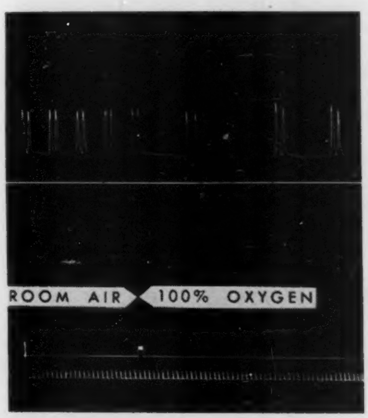

Fig. 2. Effect of 100 percent oxygen on couplet periodic breathing. Tracings are as in Fig. 1.

is supported by the observation that as the animal is progressively depressed with thiopental the respiratory pattern changes from normal, frequently through a stage of couplet breathing, to respiratory arrest. Cheyne-Stokes breathing was not seen during this transition.

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26 May 1960

Impairment of Muscle Stretch Reflexes in Tick Paralysis

Abstract. Experiments with tick-paralyzed dogs and woodchucks have shown impairment of stretch reflexes in addition to partial paralysis at the neuromuscular junction. Stretch reflexes disappear very early during paralysis, whereas nociceptive reflexes do not appear to be directly affected. The early incoordination and the ascending nature of the paralysis may be related to impairment of stretch reflex pathways.

Paralysis caused by ticks, commonly *Dermacentor andersoni* in the western United States and Canada (*1*) and *D. variabilis* in the eastern United States (*2*), is of considerable medical and veterinary importance. Paralysis is apparently caused by a toxin secreted by engorging female ticks. The progression of symptoms (see *3*) includes incoordination, muscular weakness, and flaccid paralysis. The paralysis is ascending (Landry's type); the lower limbs, the forelimbs, the cranial motor nerve functions, and the respiratory apparatus are affected sequentially. Complete recovery is rapid if the ticks are removed prior to respiratory paralysis of the victim.

Previous workers have shown failure of neuromuscular transmission during severe paralysis (*4*), and this failure has been shown to be due to a deficiency in the release of transmitter substance (*5–7*). Emmons and McLennan (*8*) have presented preliminary data which indicate that there is a central action of the toxin in addition to the peripheral action.

In the experiments herein reported (*9*), stretch reflexes were studied in three dogs and nine woodchucks *(Marmota flaviventris)* (*10, 11*) paralyzed with *D. andersoni*. Metal shields containing the ticks were taped over a shaved area of the animals' bodies (*11*). Animals were studied either at the stage of partial paralysis (incoordination of hindlimbs, little involvement of forelimbs) or of full paralysis (flaccid paralysis; slow, gasping respiration). In all cases records obtained during paralysis were compared with those obtained under identical conditions when the animal had recovered, subsequent to removal of the ticks. In some experiments pentobarbital anesthesia was used for tests during paralysis and after recovery. In two woodchucks, to avoid use of the anesthetic, the spinal cord was sectioned at the atlanto-occipital junction while the animal was under ether anesthesia. Tests were made on the paralyzed animals after elimination of the ether and were continued over an 18-hour period after removal of the ticks. Respiration and body temperature of these animals were maintained artificially.

Gastrocnemius muscle was activated by maximal electrical stimulation of the sciatic nerve. Stretch reflexes were elicited by tap of the patellar tendon or by pull of the severed Achilles tendon; controlled mechanical stimuli were delivered by appropriate solenoid devices. In some cases muscle tension was recorded on a Grass polygraph by means of a strain gauge attached to the Achilles tendon. In other experiments gross electromyograms were obtained from the muscle by means of two recording electrodes spaced 2 cm apart in the belly of the muscle (*12*).

Table 1 gives the experimental conditions and the degree of neuromuscular impairment in seven paralysis-recovery experiments. In addition, stretch reflexes alone were studied in one partially paralyzed dog and one fully paralyzed woodchuck. Muscle stretch reflexes could not be elicited in any of the paralyzed animals. Figure 1 gives representative mechanical records obtained from a fully paralyzed woodchuck and typical electromyograms from a partially paralyzed dog. It is significant that stretch reflexes were invariably absent even though neuromuscular transmission in partially paralyzed animals was only slightly reduced. Partially paralyzed animals, examined grossly, exhibited considerable muscular power. They were able to stand briefly but lacked sufficient hindlimb coordination to walk.

Transmission from dorsal root to ventral root was studied in three fully paralyzed woodchucks by electrical recording techniques described previously (*13*). Two normal woodchucks were studied for comparison. The re-

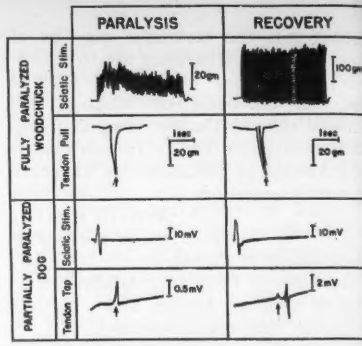

Fig. 1. Impairment of neuromuscular transmission and muscle stretch reflexes in paralysis-recovery experiments. The animals were anesthetized with pentobarbital. Arrows identify stimulus (mechanical) artifacts in records. Woodchuck: mechanical recording of muscle tension from Achilles tendon; frequency of sciatic stimulation was five pulses per second. Dog: Electromyogram recording from gastrocnemius muscle; oscilloscope traces are 50 msec in the upper row and 100 msec in the lower row.

flex discharge in normal animals consisted of a short-latency spike followed by a prolonged irregular discharge, tentatively identified as monosynaptic ($2N$) and polysynaptic responses, respectively. In one of the paralyzed animals bleeding was excessive and no transmission was observed. The ventral root discharges from the other two paralyzed animals differed from those of normal woodchucks in that the $2N$ spike was not elicited by isolated dorsal root stimuli but did appear during and following tetanic stimulation. While close comparison of such responses in normal and paralyzed animals is difficult, the results are consistent with the other evidence for impairment of stretch reflexes. In addition, since mus-

Table 1. Degree of neuromuscular impairment in paralysis-recovery experiments. EMG, electromyogram.

Animal and experimental procedure	Degree of paralysis*	Neuromuscular impairment† (%)
Dog, pentobarbital, EMG	Partial	14
Woodchuck, pentobarbital, EMG	Partial	10
Woodchuck, spinal, tension	Partial	30
Dog, pentobarbital, EMG	Full	88
Woodchuck, pentobarbital, tension	Full	92
Woodchuck, spinal, EMG	Full	77
Woodchuck, pentobarbital, EMG	Full‡	40

* Assessed from symptoms of the animal before anesthetization or section of the spinal cord. See text for criteria. † Estimated from measurements made during paralysis and again in the same animal after recovery. ‡ A 4-hour delay between the removal of ticks and the recording of the EMG allowed some recovery to occur.

cle stretch reflexes are presumably mediated by the 2*N* pathway in the woodchuck, they indicate the prominence of a central locus of action of the toxin.

Nociceptive reflexes were not quantitatively studied. Such reflexes could, however, be elicited at all degrees of paralysis. Furthermore, no evidence of impairment of polysynaptic reflex pathways was obtained from the dorsal root–ventral root experiments.

Murnaghan (*14*) and Emmons and McLennan (*8*) have recently presented data indicating that the toxin decreases conduction in peripheral nerves in addition to block of terminal branches of motor fibers (*7*). If impairment of reflexes were due only to the failure of neuromuscular transmission and to nerve block, reflex activity should be present in proportion to the degree of neuromuscular transmission. Stretch reflexes were, however, absent for all degrees of paralysis studied (see Table 1).

The present experiments do not indicate a mechanism by which such a selective block may occur. However, it is well known that the afferent fibers in the monosynaptic pathway branch extensively into fine terminals, as do the motor fibers at the neuromuscular junction. It may be conjectured that the toxin blocks fine terminal fibers at various sites in the central and peripheral nervous systems. If such is the case, its action may depend only upon the organization of the nervous pathway and not upon the type of chemical mediator released or the functions subserved.

Impairment of stretch reflexes is compatible with the symptoms of early paralysis (see *3*) and with the ascending nature of the paralysis; indeed, such symptoms can hardly be explained solely on the basis of peripheral motor block (see *6*). Incoordination, the earliest sign of impending paralysis, is not seen with curariform drugs but is observed with drugs and with surgical procedures which impair spinal reflex function. For example, interruption of afferent pathways from the hindlimbs by dorsal root section produces complete incoordination and full functional paralysis, although neuromuscular transmission is unchanged (see, for example, *12*). Thus the signs of early tick paralysis may be attributable almost entirely to the loss of stretch reflexes rather than to the slight degree of neuromuscular paralysis at this time.

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1 August 1960

Reduction of Radiation Sensitivity of Dry Bacterial Spores with Hydrogen Sulfide

Abstract. Hydrogen sulfide reduces the lethal effect of x-rays in dry spores by about 50 percent when given after irradiation, and by approximately 75 percent when present during irradiation. The first effect is the result of removal of radicals that are toxic when combined with oxygen; the second, the removal of radicals that become toxic in the absence of oxygen. With these results we construct an explanation of the action of sulfhydryl compounds in protection against radiation damage.

With the use of dry spores of *Bacillus megaterium*, we have demonstrated the participation of free radicals and other chemical species in the lethal effect of x-rays, and the relationship of oxygen to this participation (*1–4*). Free radicals and oxygen have been discussed at length [see (*5*) for recent review] in connection with the mechanism of action of chemical compounds that protect biological organisms from the deleterious effects of high energy radiation. In this study we have tested a number of compounds related to those that are efficacious in higher organisms, and the results enable us to present a theory of the mode of action of certain protective chemicals.

It is well known that the most effective protective compounds are those containing -SH and $-NH_2$ groups. Those tested here are gases at ordinary temperatures since our system gives accurate results most conveniently with gases. In this communication we report results obtained with the simplest sulfhydryl compound, hydrogen sulfide (*6*).

The spores, mounted on Millipore filters, were exposed to 50-kv (peak) x-rays in containers that allowed control of temperature and gaseous environment as previously described (*7, 8*). Colony formation was the index of survival, with the slope of the survival line being the measure of sensitivity to radiation. Methods are described fully in other papers (*1, 2, 4, 7, 8*). In this system reproducibility from experiment to experiment is good and variances are low (*4*). The differences reported in this paper are highly significant. H_2S is not toxic to the dry spore.

In Fig. 1 the data are presented. H_2S, given to the spores after irradiation in N_2 but before exposure of the irradiated spores to O_2 (curve 3), results in protection to the same extent as that brought about by the radical scavenger nitric oxide (*3, 4*). The slope is 0.0141 kr^{-1} compared to 0.0380 kr^{-1} observed when the spores are irradiated in O_2 (*8*). When O_2 is introduced to the spores irradiated in N_2 before H_2S exposure (curve 1) this reversal is not observed, the slope being 0.0270 kr^{-1}. The interpretation is the same as for the NO results: radicals are formed that are long-lived and that can be scavenged by H_2S. These radicals become irreversibly toxic to the cell if they react with O_2.

In mixtures of H_2S and O_2, sensitivities intermediate between those observed in each alone are observed (curve 2). This preliminary result is interpreted as evidence for competition between these two molecules for the radicals in question. Detailed studies of

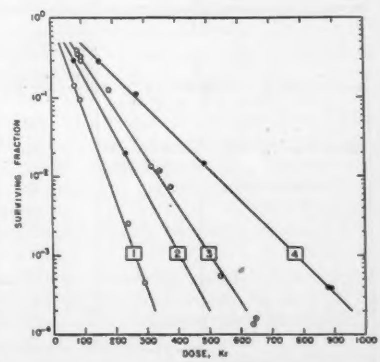

Fig. 1. Survival of dry spores of *Bacillus megaterium* when irradiated and treated as follows. Curve 1, spores irradiated in N_2, then exposed to 20 percent O_2 for 10 minutes, and then exposed to 20 percent H_2S for 15 minutes. The slope is 0.0270 kr^{-1}. Curve 2, spores irradiated in 20 percent H_2S and 80 percent air. The slope is 0.0173 kr^{-1}. Curve 3, spores irradiated in N_2, then exposed to 20 percent H_2S for 15 minutes. The slope is 0.0141 kr^{-1}. Curve 4, spores irradiated in 20 percent H_2S and 80 percent He. The slope is 0.0090 kr^{-1}.

this competition are being carried on.

When H_2S is present during irradiation (curve 4) even greater protection is observed, with the slope decreasing to 0.0090 kr^{-1}. This result indicates the presence of very short-lived (that is, lifetimes shorter than minutes, the time required for gas transfer after irradiation) radicals that can be scavenged by H_2S. These can ordinarily become toxic to the cell in the *absence* of oxygen. [It should be recalled here that nitric oxide, although it gives results equivalent to H_2S when given to the spores after irradiation, does not protect as well when present during irradiation (*3, 4*).]

In Fig. 2 we present a summary of the information at hand today concerning the radiation response in dry spores. We call this diagram the "radiation sensitivity profile." This particular profile is obtained when one uses photons of average energy about 20 kev, delivered at room temperature at about 20 kr/min to spores prepared according to our described methods. (We expect the profile to depend upon linear energy transfer, temperature, and perhaps dose rate.) This profile demonstrates that 62 percent of the total effect is dependent on O_2, 38 percent being independent of O_2. The former portion can be resolved into one associated with radicals having appreciable lifetimes, and one consisting of radiation-induced species that are toxic only if O_2 is present at the time of their formation. Possibilities concerning this class have been discussed (*1, 4*) and are under current investigation.

The new information in this note indicates that the portion which is independent of O_2, formerly called class I (*1*), is now divisible into two portions: one (class Ia) that is independent of H_2S, and therefore a measure of the "direct" effect, or else of a species that cannot be reversed by H_2S; and one (class Ib) that is reversible by H_2S only if present at the time of irradiation, and therefore one conceivably due to a very short-lived radical. Note that the radicals of class Ib are almost immediately toxic in the absence of oxygen, in contrast to those of class III that become rapidly toxic only when they react with oxygen.

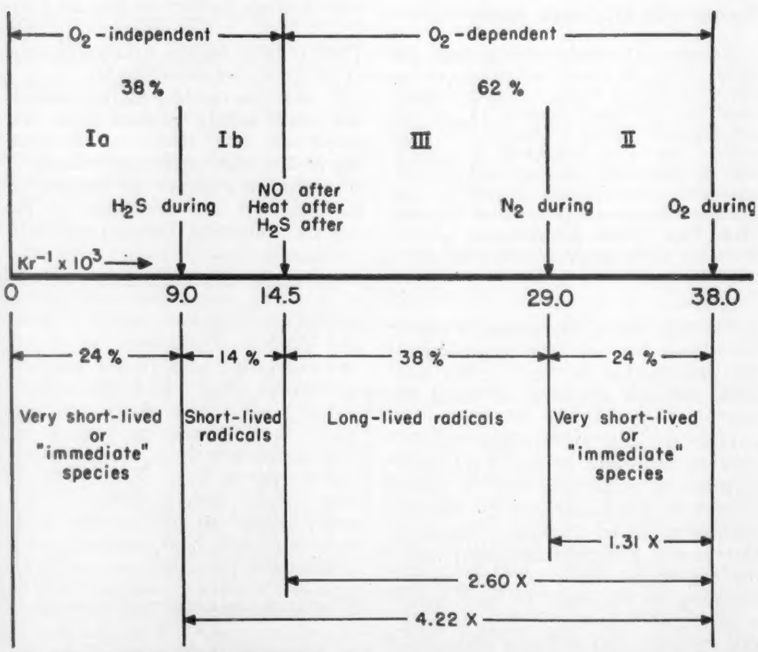

Fig. 2. The "radiation sensitivity profile" of dry spores irradiated at room temperature with 50-kv (peak) x-rays at approximately 20,000 r/min. The heavy, central, horizontal line represents slopes of survival curves. The top vertical arrows are at the values of the slopes observed under the various conditions noted. The Roman numerals refer to former terminology for describing the kinds of damage (*1*), with the subdivision of class I damage into Ia and Ib being an innovation in this report. The numbers at the bottom are the ratios of slopes observed under the indicated conditions relative to the maximal sensitivity observed.

The ratios of effectiveness observed under different conditions are noted at the bottom of Fig. 2. Sensitivity seen when the spores are irradiated in O_2 is 131 percent of that when irradiated in N_2. This is a small O_2 effect. But when the comparison is made with the sensitivity observed after postirradiation treatment with radical scavengers, the effect is seen to be 262 percent, a value of the order of the ordinarily observed O_2 effect in radiation biology.

On the basis of these results in dry spores we can suggest a general explanation of the action of sulfhydryl compounds in this and other biological systems. Sulfhydryl compounds can affect both portions of the oxygen effect by reducing O_2 tensions. When O_2 concentrations are low, the species immediately dependent upon O_2 (class II) do not become toxic, and the radicals of class III (which in the spore are very long-lived) cannot form toxic oxyradical complexes. Thus, they can be scavenged by the chemical compound before O_2 is readmitted. But the total effect of the sulfhydryl is in excess of the O_2 effect (in the case of the spore 422 percent versus 262 percent). The action of the sulfhydryl in this portion of the general effect is to scavenge very reactive, O_2-independent radicals (class Ib).

While the exact relationships between the dry and wet systems are not yet recognized, this model explains the protective action of sulfhydryl compounds under anoxic conditions demonstrated in bacteria (*9*) and in T2 bacteriophage (*10*). It also accounts for the protective action of H_2S in dry seeds (*11*).

E. L. Powers
B. F. Kaleta

Division of Biological and Medical Research, Argonne National Laboratory, Argonne, Illinois

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11. N. Nybom, A. Gustaffson, L. E. Ehrenberg, *Botan. Notiser* **4**, 344 (1952).

15 June 1960

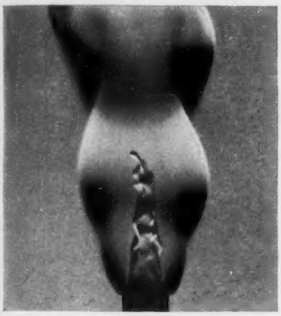
Kodak reports on:

19 pages of savvy on schlieren . . . the sweetest little old solid-state amplifier and transducer known to man . . . paste, beautiful paste

Thin air can be photographed

The technique of schlieren photography has now been debased to the point where a man can send in to Kodak for a free booklet on how to do it, can carefully read all 19 pages, and can set himself up as a schlieren man. Yes, and perhaps a case can be made that it is not necessarily immoral to go at it just that way.

Though the schlieren method of photographing refractive index gradients in gases and liquids has been around for quite a while, general literature about it is scant; most of what has been published about it dwells on some particular application. You can find packaged schlieren outfits advertised, but the advertisements are low-pressure. Everybody who is doing schlieren now learned the hard way and is entitled to respect. One such savvy schlieren group works at Battelle Memorial Institute and another at Cornell Aeronautical Laboratory, Inc.



Here is an enchanting display item from Battelle's gallery—a turbulent Bunsen flame, frozen in a 13-microsecond schlieren portrait. Areas lighter than background represent decreasing index in an arbitrary direction within the plane of the picture; darker areas represent change in the opposite direction. To measure the quantitative rate of change with distance demands the very considerable elaboration of interferometric technique. A third method, called shadow photography, delineates the second derivative of refractive index with distance. Our slim volume merely hints at the existence of these other methods. Given enough encouragement to expand it some day, we might cover them in useful detail.

To start encouraging us, send for "Schlieren Photography" to Eastman Kodak Company, Sales Service Division, Rochester 4, N. Y.

Rapid-access photography

The silver halide crystal of suitable size and suitable dislocations, with a suitable organic compound or two clinging to it, makes the sweetest little old solid-state amplifier and transducer known to man. It is doing just fine, despite a few misconceptions that have arisen due to the following circumstances:

1) The idea was developed by artists before words like "solid-state physics," "amplifier," and "transducer" were coined and even before science was recognized as profitable.

2) The crystal is employed in very large numbers, dispersed in a dried-down broth from hides and bones. Superficially regarded, this seems archaic. By referring to the preparation as a "photographic emulsion," the notion is dispelled.

3) Memories from childhood suggest that after a photographic emulsion is exposed, one must wait until Dad brings the results home from downtown the week after next. This is no longer true.

Purpose of this message is to make it perfectly clear that today the delivery of photographic results within virtually any desired time interval after exposure is wholly feasible technologically. There are many ways of accomplishing quick delivery, some currently on the market and others on the way. The manufacturer wagers on what the public will buy. As far as goods for the general public are concerned, that's the way it has to be. But on goods for the professionally technical public—rational, organized, deliberate, articulate—*must* the betting be so blind?

We have had a flash of genius. Let's ask them first what they want! Then, as patterns appear in the answers, markets can be defined and gauged. If this works, rapid-access and simplified technical photography will encounter fewer custom problems to be solved at custom prices or else given up for less satisfactory alternatives.

Responsible organizations confronted with technical problems, major or minor, where rapidly or instantaneously available photographic images would be helpful, are invited to describe their wants to Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

Amylose and culture

Spaghetti and macaroni are basic.

The idea of making wheat flour up into a paste and drying it for future use must have come very early. Enter esthetics. The human spirit must be nourished along with the human body. For reasons apparently unrelated to biological metabolism, the paste must be dried in certain shapes, *and the integrity of these shapes must be preserved right to the pearly portal of the alimentary tract.* This principle is ancient: the ancient Romans ate spaghetti with cheese; the ancient Japanese ate macaroni pressed from a paste of cooked rice.

When spaghetti or macaroni is cooked for too long or allowed to stand cooked, the human spirit is offended. The morsels of *pasta* revert to a sticky paste, millenia of cultural advance undone because amylose has gone into solution and then has loosely hydrogen-bonded itself into a net of slime. But for this unfortunate tendency, the world's food supply would be less dependent on specialized durum wheats. Without them, the spaghetti and macaroni would get even stickier even faster.

The problem now appears to be as soluble as the amylose itself.

First fruits of the victory can already be tasted. Try any of the up-to-date dehydrated potato-flake brands. See how the dish instantly prepared from it compares with freshly and expertly cooked home-whipped potato.

Whatever the future holds for spaghetti and macaroni, the reason the instant-potato thing works out so well is that the processors add a very small percentage of pure monoglyceride. It complexes the dissolved amylose so securely that even the familiar iodine-blue test can scarcely find it.

These Myverol Distilled Monoglycerides *we prepare by glycerolysis of familiar vegetable and animal food fats. They are officially recognized as safe. Investigators who would like samples of them with which to try remedying stickiness in any starchy foods are invited to write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Kodak

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

Letters

The Incorrect Use of "Base"

The ions of calcium, magnesium, and potassium, especially when they are held as exchangeable ions on colloids, are often referred to collectively as "bases" by workers in soils and some related subjects. This absurd mistake is made by men of some repute and extends to recent textbooks, which must thereby confuse the next generation of students. The offenders may excuse themselves by saying that they want to distinguish calcium and magnesium ions (which produce trivial acidity on interaction with water) from aluminum and ferric ions (which produce much acidity), and that *base* is the only word they can think of for the former.

It is apparently useless in dealing with such people to point to the work of Brønsted of over 30 years ago, so perhaps we should make it easier for them to reform. In fact, no short term exists for "rare-earth cations of charge one or two other than beryllium." "Nonhydrolyzing cations" (which comes closer to the intention) is also too long. The word *alkalon* has been suggested, by analogy with *lanthanon,* which could replace the clumsy "elements of the rare earths." Whether or not *alkalon* is acceptable, it is important that a short alternative term be invented, in order to put an end to the present misuse. Editors might then be bold enough to refuse to print the word *base* when it is used, as it commonly is, to mean "very weak acid."

G. W. LEEPER
University of Melbourne, Victoria, Australia

Blood Typing of Aged Material

Madeleine Smith's article on "Blood groups of the ancient dead" [*Science* **131**, 699 (1960)], published under the heading "Current problems in research" and summarizing the work done to date in blood typing of aged bone or tissue, gives the impression that paleoserology presently provides a useful tool for research into the history and genetics of ancient populations. Unfortunately, this is not the case, at least at present.

Smith, in summarizing the developments in technique and reports of typings since the beginning work of Boyd in 1933, fails to include in her bibliography the paper by F. P. Thieme and C. M. Otten entitled "The unreliability of blood typing aged bone" [*Am. J. Phys. Anthropol.* **15**, No. 3 (1957)],

which is crucial to the subject under discussion. To summarize briefly the results reported in that paper, tests were conducted on aged samples of bone from individuals of known blood type, on stains made from blood of known type, aged and then dried; and on antigens of known blood type that had been subjected to the action of bacterial enzymes. Forty-seven percent of the 19 bone samples buried over 2 years and tested gave incorrect results. Results were incorrect from 37 percent of blood samples aged three weeks, then dried on paper and tested; from 53 percent of samples aged two months; and from 100 percent of blood samples polluted with 0.5 gram of soil and aged 2 weeks before the dried stains were tested. Each of the known ABO types later tested as another type in at least one case. Furthermore, the established effect which bacterial enzymes have on blood-group antigens was confirmed. In the presence of certain enzymes one antigen may be changed so as to behave in the inhibition test like another type.

A variety of factors may combine or act singly to cause the observed unreliability of conclusions about the blood type of aged material. The inhibition test itself is not a direct and reliable method and gives frequent nonspecific reactions in tests of ABO or other antigens which are not fresh. The frequent unreliability of tests also results from the presence of adventitious antigenic elements indistinguishable from blood-group substances, or from the influence of bacterial enzymes in transforming or destroying the specificity of blood-group substances. Under such conditions, the positive reactions obtained with traditional techniques should be regarded as far from reliable.

Possibly the future will bring direct and reliable tests of the antigens, as indicated by findings suggestive of group-specific features. When this is accomplished, it may then be possible to get reliable evidence which can be used in studying the blood types of ancient populations.

F. P. THIEME
University of Washington, Seattle

I must offer Thieme my regrets that in my review I do not quote his 1957 paper. My bibliography was not exhaustive; however, I believe that I did discuss the major points mentioned in his paper and gave some idea of what progress had been made in their study.

I note that on the basis of the results quoted in his paper, Thieme considers my views too optimistic. I would suggest, with all courtesy, that those re-

sults are open to some criticism. Thieme has himself attacked the techniques used but does not seem to make due allowance for technical error in estimating the accuracy of his own results. There is much to question in the methods he describes; for instance, I have discussed elsewhere the inadvisability of using AB serum as a diluent in inhibition tests on bone, and in my own laboratory have found that results obtained with this method are never clear or reliable. Perhaps it is permissible to suggest, also, that percentages based on a series of eight A's, three B's, one AB, and seven O's cannot be used to finalize an argument. Thieme's paper is a significant contribution to the subject, but it would be disappointing if, at a stage in research when all workers are agreed as to the technical inadequacies, further study should be abandoned and a pessimistic attitude taken on such scanty evidence.

MADELEINE SMITH
Subdepartment of Anthropology, British Museum, London, England

Not Cooking with Gas

After reading in your editorial [*Science* **132**, 113 (15 July 1960)] that it is impossible to cook potatoes by boiling at 11,000 feet, "even boiling overnight," I drove up to Climax, Colorado, a town of about 2500 which flourishes at 11,320 feet altitude. There I made a door-to-door survey, asking housewives how long it takes to boil potatoes in Climax. All of them said the same: *1 hour*; with a pressure sauce pan, 10 minutes.

A. R. PATTON
Department of Chemistry, Colorado State University, Fort Collins

This was Darwin's statement, not ours [*see* A Naturalist's Voyage in the Beagle, *Publ. 104 (Everyman's Library, reprinted 1930, Dent, London; Dutton, New York), pp. 310-311*]. *Darwin's relevant comments are that the elevation "was probably not under 11,000 feet, and the vegetation in consequence exceedingly scanty. The root of a small scrubby plant served as fuel, but it made a miserable fire, and the wind was piercingly cold . . . the potatoes, after remaining some hours in the boiling water were nearly as hard as ever. The pot was left on the fire all night, and the next morning it was boiled, but yet the potatoes were not cooked." These conditions are far from comparable to those obtaining in modern kitchens in Climax, Colorado, but at any rate, Darwin was right in principle.*—Ed.

Meetings

Forthcoming Events

October

24–26. Medical and Biological Aspects of the Energies of Space, symp. (School of Aviation Medicine, USAF Aerospace Medical Center), San Antonio, Tex. (J. Harmon, Symposium Coordinator, Southwest Research Inst., P.O. Box 2296, San Antonio 6)

26–28. Society for Industrial Microbiology, Conf. on Antimicrobial Agents, Washington, D.C. (SIM, 2000 P St., NW, Washington 6)

27–28. Cellulose Conf., 3rd, Syracuse, N.Y. (Cellulose Research Inst., State Univ. College of Forestry, Syracuse Univ., Syracuse 10)

27–28. Electron Devices, 6th annual, Washington, D.C. (J. Hornbeck, Bell Telephone Labs., Murray Hill, N.J.)

27–29. American Soc. for Aesthetics, Brooklyn, N.Y. (J. R. Johnson, Cleveland Museum of Art, Cleveland 6, Ohio)

27–29. International Assoc. of Milk and Food Sanitarians, Chicago, Ill. (V. T. Foley, Kansas City, Missouri, Health Dept., City Hall, Kansas City)

28–29. Society for the Scientific Study of Religion, 20th, New York, N.Y. (W. H. Clark, Hartford School of Religious Education, Hartford 5, Conn.)

29–3. Photoelasticity, intern. symp., Chicago, Ill. (P. D. Flynn, ISP, Illinois Inst. of Technology, Chicago 16)

31–2. Association of Military Surgeons of the U.S., Washington, D.C. (R. E. Bitner, Suite 718, New Medical Bldg., 1726 Eye St., NW, Washington)

31–2. Electrical Techniques in Medicine and Biology, 13th annual conf., Washington, D.C. (G. N. Webb, Room 547, CSB, Johns Hopkins Hospital, Baltimore 5, Md.)

31–2. Geochemical Soc., Denver, Colo. (K. B. Krauskopf, Geology Dept., Stanford Univ., Stanford, Calif.)

31–2. Geological Soc. of America, Denver, Colo. (F. Betz, Jr., 419 W. 117 St., New York 27)

31–2. Society of Economic Geologists, Denver, Colo. (H. M. Bannerman, U.S. Geological Survey, Washington 25, D.C.)

31–2. Society of Rheology, annual, Pittsburgh, Pa. (J. H. Dillon, Textile Research Inst., Princeton, N.J.)

31–4. American Public Health Assoc., San Francisco, Calif. (B. F. Mattison, APHA, 1790 Broadway, New York 19)

November

1–3. International Cong. on Experimental Mechanics, New York, N.Y. (R. Guernsey, Jr., Soc. of Experimental Stress Analysis, General Engineering Lab., General Electric Co., Schenectady 5, N.Y.)

1–16. International Electrochemical Commission, New Delhi, India. (American Standards Assoc., 70 E. 45 St., New York 17)

2–4. Plasma Physics, 2nd annual, Gatlinburg, Tenn. (A. H. Snell, Oak Ridge Natl. Lab., Oak Ridge, Tenn.)

2–4. Society for Experimental Stress Analysis, Berkeley, Calif. (W. W. Murray, Massachusetts Inst. of Technology, Cambridge)

2–5. American Soc. of Parasitologists, Los Angeles, Calif. (F. J. Kruidenier, Zoology Dept., Univ. of Illinois, Urbana)

2–5. American Soc. of Tropical Medicine and Hygiene, Los Angeles, Calif. (R. B. Hill, 3573 St. Gaudens Rd., Miami 33, Fla.)

2-5. American Speech and Hearing Assoc., Los Angeles, Calif. (K. O. Johnson, 1001 Connecticut Ave., NW, Washington 6)

3–4. Electrostatic Propulsion, conf., Monterey, Calif. (J. M. Sellen, Thompson Ramo-Wooldridge, Inc., 8433 Fallbrook Ave., Canoga Park, Calif.)

3–4. Muscle as a Tissue, conf., Philadelphia, Pa. (Division of Research, Lankenau Hospital, Philadelphia 31)

4–5. West-Central States Biochemical Conf., Lincoln, Neb. (J. H. Pazur, Dept. of Biochemistry and Nutrition, Univ. of Nebraska, Lincoln)

4–6. Assoc. of Clinical Scientists, Washington, D.C. (R. P. MacFate, 54 W. Hubbard St., Chicago 10, Ill.)

5. Society for Industrial and Applied Mathematics, Philadelphia, Pa. (G. Kaskey, Remington Rand Univac, 1900 W. Allegheny Ave., Philadelphia)

7–10. Society of Exploration Geophys-

icists, 30th annual intern., Galveston, Tex. (C. C. Campbell, Box 1536, Tulsa, Okla.)

8–10. Forensic Sciences, 2nd symp., Washington, D.C. (Director, Armed Forces Inst. of Pathology, Washington 25)

9–10. Use of Secondary Surfaces for Heat Transfer with Clean Gases, symp., London, England. (Secretary, Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1)

9–11. Clinical Chemistry Methods, symp., Cleveland, Ohio. (A. Hainline, Cleveland Clinic, 2020 E. 93 St., Cleveland 6)

10–12. Geological Soc. of America, 73rd conv., Denver, Colo. (H. R. Aldrich, GSA, 419 W. 117 St., New York 27)

10–12. National Assoc. of Geology Teachers, Denver, Colo. (F. Foote, Dept. of Geology, Williams College, Williamstown, Mass.)

10–13. Pacific Coast Fertility Soc., Las Vegas, Nev. (A. C. Wineberg, 3120 Webster St., Oakland, Calif.)

11–12. Paleontological Soc., Denver, Colo. (H. B. Whittington, Harvard Univ., Cambridge 38, Mass.)

13–16. Society of American Foresters, 60th annual, Washington, D.C. (H. Clapper, SAF, 825 Mills Bldg., Washington 6)

14–17. Magnetism and Magnetic Materials, 6th annual conf., New York, N.Y. (L. R. Bickford, Jr., I.B.M. Research Center, Yorktown Heights, N.Y.)

14–18. American Soc. of Agronomy, Chicago, Ill. (L. G. Monthey, 2702 Monroe St., Madison 5, Wis.)

14–18. Nuclear Ship Propulsion, symp., Taormina, Sicily. (International Atomic Energy Agency, 11 Kärntner Ring, Vienna 1, Austria)

15–16. Engineering Application of Probability and Random Function Theory, symp., Lafayette, Ind. (J. L. Bogdanoff, School of Aeronautical and Engineering Sciences, Purdue Univ., Lafayette)

16–19. Society of Naval Architects and Marine Engineers, annual, New York, N.Y. (W. N. Landers, SNAME, 74 Trinity Pl., New York 6)

17–19. Extrapyramidal System and Neuroleptics, intern. symp., Montreal, Canada. (J.-M. Bordeleau, Dept. of Psychiatry, Univ. of Montreal, Montreal)

17–19. Surgery of Endocrine Organs, symp., New York, N.Y. (Office of the Associate Dean, New York Univ. Post-Graduate Medical School, 550 First Ave., New York 16)

17–20. American Anthropological Assoc., Minneapolis, Minn. (B. J. Meggers, 1530 P St., NW, Washington 5)

17–20. Southern Thoracic Surgical Assoc., Nassau, Bahamas. (H. H. Seiler, 517 Bayshore Blvd., Tampa 6, Fla.)

18–19. American Medical Writers' Assoc., Chicago, Ill. (H. Swanberg, 510 Maine St., Quincy, Ill.)

21–23. Fluid Dynamics, annual, Baltimore, Md. (R. J. Emrich, Div. of Fluid Dynamics, APS, Dept. of Physics, Lehigh Univ., Bethlehem, Pa.)

24–25. American Physical Soc., Chicago, Ill. (K. K. Darrow, APS, 538 W. 120 St., New York 27)

24–26. Central Assoc. of Science and Mathematics Teachers, 60th annual conv., Detroit, Mich. (L. A. Conrey, School of Education, Univ. of Michigan, Ann Arbor)

(See issue of 16 September for comprehensive list.)

New Products

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Neither Science nor the writer assumes responsibility for the accuracy of the information. All inquiries concerning items listed should be addressed to the manufacturer. Include the department number in your inquiry.

■ POLARIZATION INTERFEROMETER ACCESSORY for Reichert reflected-light microscopes permits assessment of surface finish without contact. The interferometer is placed between the vertical illuminator and the objective of the microscope. Its most essential part is a double quartz wedge arranged between crossed polarizing elements. A system of interference fringes appears in the field of view of the microscope that can be interpreted to deduce surface configuration of the object. (William J. Hacker & Co., Dept. Sci798, P.O. 646, West Caldwell, N.J.)

■ COMPOUND SINE TABLE, available in five sizes from 9 to 36 in. in diameter, permits angles up to 45° to be set. Movement is provided by a hemisphere riding in a conical seat. Sine settings are obtained by insertion of gage blocks under two ball-ended pins spaced 90° apart. Accuracy is said to be ±10 sec. (Engis Equipment Co., Dept. Sci809, 431 S. Dearborn St., Chicago 5, Ill.)

■ LINEAR ENCODER SYSTEM measures length by unreeling a 0.070-in. diameter steel cable from an aluminum drum. A take-up motor keeps the cable under tension. As the cable is pulled out, the drum rotates ½ turn for each foot of cable. The drum is geared at 5-to-1 ratio to an encoder assembly that converts rotation into an output signal digitally coded in feet and inches. The drum holds 104 ft of cable in a helical groove. (Datex Corp., Dept. Sci820, 1307 S. Myrtle Ave., Monrovia, Calif.)

■ MUTUAL CONDUCTANCE METER provides direct reading of mutual conductance with accuracy said to be ±2 percent. A calibration circuit is built in. Thirteen multirange meters permit complete tube analysis under standard or nonstandard operating conditions. Five independent regulated power supplies are provided. A grid current meter is included. A completely automatic model is available on special order. (Westmore, Inc., Dept. Sci836, 137 South Ave., Fanwood, N.J.)

■ DIGITAL MULTIMETER features all-electronic solid-state circuitry. Voltage is measured in five ranges from 0.00001 to 999.9 volts; d-c ratio, from 0.0001 to 99.99 in three ranges; a-c voltage, from 0.0001 to 999.9 in four ranges; and resistance, from 0.1 ohm

to 999.9 kohm in four ranges. Average reading time for d-c voltage is 50 msec; 20 msec for d-c ratio; 2 sec for low-frequency a-c; and 0.5 sec for frequencies 400 cy/sec and higher. Ranging and polarity indication are automatic. Temperature stability and drift characteristics are said to be better than 0.005 percent. (Electro Instruments Inc., Dept. Sci814, 3540 Aero Court, San Diego 11, Calif.)

■ SEMICONDUCTOR PREPARATION FURNACE consists of two or more tubular furnaces mounted on a common axis to permit zone refining, directional freezing or slow crystallization, seeding, and crystal growing in the quartz work tube which runs through all furnace chambers. Each furnace is supplied with sufficient shunt taps to establish any reasonable temperature profile within the chamber. Sharp temperature gradients between adjoining units may be established by adjusting furnace spacing. Once adjusted for the correct spacing, the furnaces can be driven as a unit on ball bushings along the support stand at speeds between ⅛ and 6 in./hr. Length of stroke is limited only by the length of the support stand chosen. (Marshall Products Co., Dept. Sci835, 270 W. Lane Ave., Columbus 2, Ohio)

■ VIBRATION METER accepts input from piezoelectric as well as seismic type transducers. Up to six transducers can be used simultaneously. One at a time can be selected by a function switch. Built-in networks integrate and differentiate the inputs to give direct velocity, displacement, and acceleration measurement. Acceleration range is 0 to 1000 grav; velocity, 0.01 to 100 in./sec; displacement, 0.001 to 10 in. (Southwestern Industrial Electronics Co., Dept. Sci840, 10201 Westheimer Rd., Houston 27, Tex.)

■ RADIOACTIVE MATERIALS HANDLER handles weights up to 150 lb and operates up to 200 ft from the operator. It is mounted on a standard fork-lift truck. Handling arms, 3 ft long, have 360-deg shoulder rotation, 30-deg shoulder bend, and 120-deg elbow bend. Jaw grip pressure varies from 10 to 800 lb. Two television cameras have continuous focus from 12 in. to infinity. Four speeds forward and reverse are provided with maximum speed 2 mi/hr. Capability of positioning of objects in three dimensions to within 1/16 in. is said to be achieved with 35 hr operating experience. (Hughes Aircraft Co., Dept. Sci842, Culver City, Calif.)

JOSHUA STERN

National Bureau of Standards, Washington, D.C.

SUPPLIES AND EQUIPMENT

BOOKS AND MAGAZINES

PERSONNEL PLACEMENT

POSITIONS WANTED

(a) **Poultry Nutrition**, Ph.D. **1960, biochemistry** minor; available for research appointment. (b) **Young Parasitologist**, Ph.D., biochemistry minor; prefers veterinary pathology, public health or pharmaceutical research. S10-1 Medical Bureau, Inc., Science Division, Burneice Larson, Chairman of the Board, 900 North Michigan Avenue, Chicago. X

POSITIONS OPEN

(a) **Bacteriologist** and (b) **Biochemist**; M.S. required to head respective sections, 500-bed general hospital, eastern metropolitan area. (c) **Bacteriologist**, B.S., M.S., to head section, supervise two technologists; 8000–10,000 bacteriological tests yearly; 500-bed general hospital; minimum $6000; Mideast. Science Division, Woodward Medical Bureau, Ann Woodward, Director, 185 North Wabash, Chicago. X

BIOCHEMIST to conduct independent programs of isolation and identification of small molecule intermediates and cofactors of mitochondrial oxidative phosphorylation. Originality and creativity desireable. To associate with protein chemist and physical chemist in primarily basic biochemistry group. Modern equipment including automatic chromatography, electrophoresis, and radioactivity laboratory is provided. Adequate research funds available. Box 188, SCIENCE.

BIOCHEMIST

Ph.D. Protein chemistry experience, initiative essential. Independent basic research project. Salary open. Write J. N. Sandman, c/o Deborah Hospital, 901 Walnut Street, Philadelphia, Pa., or call HObart 1-0953 in Riverside, New Jersey.

CHEMIST

Experienced in drug analyses. Able to apply modern physical methods. Willing to work at bench and assume supervision of others. Long-established independent laboratory, central Philadelphia. State training and experience. Immediate opening, starting date may be as late as 1 November. Replies confidential until after personal interview.

Box 179, SCIENCE

(a) **Clinical Research Director**, M.D. or Ph.D. in pharmacology/chemistry or skilled scientist to be groomed as director; drug evalution studies, research and administrative duties for leading drug firm; $13,000–$20,000; Midwest. (b) **Biochemist** to head department in 400-bed hospital; qualified in clinical chemistry, research and teaching; $7000–$9500; Pacific Northwest. (c) **Microbiologist** with chemotherapy experience to plan and conduct research-development program on newly synthesized compounds for chemical firm; around $10,000; East. (d) **Toxicologist** to supervise and conduct tests in morgue laboratory; $9000; Midwest. (e) **Biochemist**, M.D. or Ph.D. for therapeutic research on cardiovascular diseases in pharmaceutical research division; $10,000 up; East. (f) **Bacteriologist** with Ph.D. or M.S. to head hospital section; $8000 up; Florida. (g) **Physiologist** for human factor research; Midwest. (h) **Pharmacologist** for research and product development with animal studies for pharmaceutical firm; $8000–$10,000; Midwest. (Please write for details; also many other positions available through our nationwide service.) S10-1 Medical Bureau, Inc., Science Division, Burneice Larson, Chairman of the Board, 900 North Michigan Avenue, Chicago. X

FOOD CHEMIST

A large, expanding food processing company located in Northern New Jersey, has an immediate opening for a recent B.S. or M.S. graduate in Microbiology & Biochemistry to assist in basic research program. Some industrial experience in the above is desirable.

Salary commensurate with qualifications and experience. Liberal fringe benefits; 35-hour week. Send résumé stating age, qualifications and salary desired to:

Box 186, SCIENCE

POSITIONS OPEN

Pharmacueutical Chemist. Two men with Ph.D. degrees or equivalent training (with or without industrial experience) required in the Pharmaceutical Product Development Department of a large ethical pharmaceutical company in upstate New York. Both positions involve research on pharmaceutical dosage forms. One man should also have a fairly strong background in organic chemistry. Work requires creativity and imagination. Excellent starting salaries and fringe benefits. Expansion of the company presents opportunities for advancement. Box 187, SCIENCE. 10/14, 21, 28

Predoctoral and Postdoctoral Training Programs in Anatomy are available for qualified students. Stipends range from $1800 to $4200 for undergraduates, starting at $6000 for postdoctoral fellows. Tuition and a modest travel allowance are provided for. The department has ten full-time faculty members, all with active research programs. Training may include electron microscopy, tissue culture methods, phase cinematography, autoradiography, histochemistry, medical genetics, experimental endocrinology, and modern techniques for investigation of the nervous system. The program includes opportunities for training at other divisions of the university in accord with the desires and best interests of the student. For further information please write to the Chairman, Department of Anatomy, The University of Texas Medical Branch, Galveston, Texas. 3/25; 9/2; 10/7

RESEARCH ASSISTANT, B.S. or higher. Conscientious person with good college record in chemistry and willingness to learn. Desired for work on the central nervous system employing biochemical and biophysical techniques. Salary consistent with training and experience. Midwestern university.

Box 184, SCIENCE

RESEARCH MICROBIOLOGIST

Ph.D. (under 35) or equivalent experience. Interest in **IMMUNOLOGY, VIROLOGY,** or **TISSUE CULTURE** desirable but not necessary.

Opportunity with an excellent future in an expanding program in vaccines and chemotherapy with an ethical manufacturer of pharmaceuticals and biologicals.

POSITION OFFERS:

- Profit sharing
- Liberal fringe benefits
- Modern laboratories and equipment.

Send résumé and salary requirements in confidence to:

DIAMOND LABORATORIES,
RESEARCH DIVISION
2538 S. E. 43rd Street
Des Moines, Iowa

FELLOWSHIPS

THE WEIZMANN INSTITUTE OF SCIENCE
Rehovoth, Israel

Announces the Chaim Weizmann Memorial Fellowships* for the academic year 1961–62.

These annual fellowships in the natural sciences are tenable for a period of 12 months. They are intended for scientists with several years of postdoctoral research experience.

It is expected that the candidate will have worked in a field close enough to one of the subjects under investigation at the Weizmann Institute of Science so that he will be able to join an existing research team.

The stipend includes round-trip fare by air for the scientist and his family and an adequate living allowance in Israel in local currency. The Institute endeavours to help find suitable accommodation.

Applications should reach the Academic Secretary, the Weizmann Institute of Science, Rehovoth, Israel, *not later than 1 December 1960.* Further particulars and application forms may be obtained from the Academic Secretary.

* Established by the Weizmann Memorial Foundation.